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WATER LAW AND LEGISLATION: HOW TO USE THEM TO OBTAIN OPTIMUM RESULTS FROM WATER RESOURCES

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Preface

1. The purpose of this paper is to treat in depth the legal topics and criteria 1/ dealt with in the Secretariat document prepared for the Mar del Plata Conference in connexion with item III of its agenda. 2/ It is hoped that this will contribute to a more effective use of water legislation as a tool for coping with present and future problems encountered in carrying out sound water policies.

2. The International Association for Water Law, a non-governmental organization in consultative status with the Economic and Social Council, held its second international conference at Caracas in February 1976. The agenda of that conference had been prepared in anticipation of the Mar del Plata Conference because the Association's conference had been previously designated by the Secretary-General of the United Nations as one of the preparatory meetings of experts for the Mar del Plata Conference. The Caracas Conference had in its turn received, and had examined as a matter of prime importance, the results of another conference which had preceded it, namely, the Conference on Global Water Law Systems, 3/ held at Valencia, Spain, in September 1975. The number and the high professional standing of the legal experts from more than 50 countries, who, together with experts from other fields and the representatives of 44 Governments, took part in the two conferences, are a guarantee that the conclusions and recommendations 4/ adopted at those conferences reflect the "state of the art" of the matters being dealt with here in 1975-1976. Those conclusions and recommendations are therefore taken fully into account in this paper.

3. The same is true of the views put forward in 1972 by a Panel of Experts appointed by the Economic Commission for Asia and the Far East (ECAFE) and embodied in a document issued by that Commission. 5/ While that document is mainly concerned with the water codes of the countries of the EC/FE region, it also makes reference to some countries outside that region.

1/ Matters relating to the bodies responsible for the administration and management of water resources are dealt with only in so far as they concern the legal regulation of such bodies and the rights of those who are subject to their administration.

2/ E/CONF.70/CBP.3. Policy options.

3/ See George Radosevich The International Conference on Global Water Law Systems in review, in: International Association for Water Law, "Second International Conference on Water Law and Water Management - working papers" (Caracas, 1976), vol. 1, p.1. Nine "considerations" were adopted by the Valencia Conference by consensus on 8 September 1975.

4/ See Vol. 17 of the "Working Papers" referred to in the preceding foot-note. This contains, in English and Spanish, the 52 recommendations adopted by the Caracas Conference.

5/ Guidelines for the Drafting of Water Codes, United Nations publication, Sales No. E.74.II.F.2.

4. It is worth noting that most of the Caracas recommendations were adopted by consensus. Some, however, were put to the vote, and it may be presumed that there was some difference of opinion regarding them. This reflects a circumstance of some importance, which is noted in the Secretary-General's document, 6/ namely, that the laws and legal institutions concerned with water are not transferable, without adaptation, from one country to another, and thus any attempt to obtain a consensus on recommendations in this matter seems to be an exercise in futility.

5. The wide range of the branches of knowledge that are reflected in the conclusions and recommendations in question - as regards both the topics dealt with and the specialities of the participants in the relevant conferences - is attributable to the very nature of water law and legislation and to the effectiveness of its role as an instrument in the implementation of water policy.

6. While accentuating certain of the ECAFE, Caracas and Valencia recommendations, this paper will also try to reflect the current trend towards, and the experience with, the integration of water law with the much broader, but not entirely analogous, areas of natural-resources law and environmental law. 7/

1. The golden rule: there is no golden rule 8/

7. The Valencia Conference (1975) identified the following systems of water law among those existing in the world: French, Spanish, British, Italian, Soviet, Hindu-Bali, Moslem, Latin American, Israeli, United States and Asian, each with its own particular characteristics. 9/ The areas in which these systems apply embrace both the countries in which the systems originated and the countries which came under their influence during the historical period of colonization. More recently, other areas have come under the influence of these systems by reason of both bilateral and multilateral technical assistance activities. Moreover, within each area the particular systems have undergone a certain degree of change in the process of adaptation to local conditions. This has occurred even within a single country - such, for example, as the United States of America, where in the matter of granting water use rights there exist side by side systems as dissimilar as riparian rights and rights of prior appropriation. 10/

6/ See document referred to in foot-note 2.

7/ See documentation of the FAO Regional Seminar of Experts on Environment and Development (Bogota, July 1976), especially documents RLAT 801/76/22 (J. Mayda), 24 (G. J. Cano) and 25 (J. Carrizosa).

8/ G. Bernard Shaw.

9/ See document referred to in foot-note 3.

10/ G. J. Cano Evolución histórica y geográfica del derecho de aguas y su papel en el manejo y desarrollo de los recurses hídricos /Historical and geographical evolution of water law and its role in the management and development of water resources/ (Valencia, 1975), International Association for Water Law, paras. 10-14. English version included in the proceedings of the Valencia Conference, 1975.

8. All this is emphasized here in order to repeat the appeal already addressed to the framers of water-use laws, namely, that these laws cannot be copied. The law-making experience of others - both where they have been successful and, even with greater reason, where they have failed - is valid and useful, and even indispensable, as an aid in forming opinions and deciding on solutions, but it cannot be relied on indiscriminately. It must be adapted, not adopted, and the local ingredients (physical, historical, human) must be added. This is what was recommended at Caracas 11/ with regard not only to areas of national scope but also to the smaller water-resource management or administration areas of a given country, for even within the same country circumstances can vary from one area to the other.

2. The drafters of water laws and the persons for whom they are intended

9. While the drafting of laws is a task for legal experts, the drafting of water laws, as mentioned in paragraph 5 above, is a task for legal experts with a specialized knowledge of various subjects, working with the aid of experts in related scientific disciplines - for example, hydrologists, hydro-geologists, meteorologists, engineers, economists, administrators, sociologists and the like. This inter-disciplinary character of water law was recognized both at Valencia and at Caracas, 12/ but at the Caracas Conference, there was, in addition, considerable discussion concerning the critical world shortage of not only legal experts but also economists and administrators possessing the kind of education and training referred to. On the basis of the number of legal experts in water law who make up the non-governmental organization which caters for them, the average comes to less than two per country. Thus, at Caracas, 13/ there was detailed discussion of the type and methods of education needed (an "active" type of teaching was advocated), and it was recommended that Governments and the specialized agencies, and more particularly the United Nations University, should set up special chairs and institutes to fill this vacuum and should promote the necessary scientific research in these fields. One example - IMELA, which operates in Argentina with assistance from a UNDP/United Nations project - was cited as worthy of being given world-wide, or at least regional, scope.

10. Water users, as well as persons concerned with water use or its harmful effects, are also in need of education or at least of information on the legal aspects of water use. In some areas, where there is an age-old tradition of water use, the inhabitants have perhaps never studied water law, but they are certainly familiar with it at least in unwritten form. In other areas, however, at least the principles on which this law is based should be explained to all the persons concerned. In some instances, a knowledge of the regulations in force is a secret reserved for the few, especially where responsibility for enforcement of the regulations is scattered about among a number of different agencies or where they have not been given adequate dissemination. This is a problem that demands a solution.

11/ Caracas, 40. (Throughout the rest of this document, the numeral as in this foot-note refers to the number of the relevant recommendation adopted by the particular conference.)

12/ Caracas 4; Valencia 9.

13/ Caracas 44 to 47, 48 (b) and 51.

3. Role of policy-making and legislative authorities

Role of users

11. Water legislation is not an end in itself: it is only one of the various instruments for giving effect to the water policies which it should reflect. This was stated at both Caracas and Valencia. 14/ Accordingly, legislation which is not preceded by (or does not explicitly involve) the adoption of certain policies is unlikely to be effective. The policies may be adopted before the legislation and may even originate with another governmental body.

12. The law can - and should - establish a legal framework within which policy-makers and planners must work. 15/ In some countries, this legal framework is determined initially by the Constitution. As recommended in detail at Caracas, the law may determine the type and variety of information to be gathered, the procedures to be followed (for example, public hearings) and the sectors of opinion which must be heard in order to legitimize the policy-making process. Such a system makes it possible to avoid taking decisions not based on adequate information and to eliminate arbitrariness and favouritism with respect to certain sectors, regions or individuals. When the law establishes such a framework, this should accord judges the right to judge, not whether policy decisions are correct or appropriate, but whether the process leading up to their adoption satisfied the legal requirements. 16/ Even these procedures and legal techniques, which are necessary to safeguard the proper planning and policy-making processes, must, according to the Caracas recommendations, 17/ be evaluated in order to determine whether their economic, social and ecological cost justifies their use and whether better alternative techniques may not exist. At Caracas, it was recommended that, to these two factors, namely, "policies" and "legislation", there should be added a third, thus forming an inseparable triad. That third element is a water development plan for each country 18/ including a plan - adopted by law - for each river basin. 19/

13. The term "legislation" is used in this document in the broad sense of legal norms which apply to all. It includes: constitutional clauses, written laws passed by parliaments or other legislative bodies, agreements and orders of

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14/ Caracas 4; Valencia 7.

15/ Caracas 15, 25; G. Cano Aspectos institucionales y legales del planeamiento hídrico /Institutional and legal aspects of water resources planning/, International Seminar on Water Resources Planning (Mexico, 1972), vol. 2.

16/ Sandford D. Clark, Legal problems associated with the role of planning in water resources management. See document referred to in foot-note 3, vol. 5, p. 460.

17/ Caracas 15 (e), 26.

18/ Caracas 17.

19/ Caracas 34.

ministerial cabinets, presidential decrees and executive orders, ministerial resolutions, ordinances of municipal deliberative bodies, and regulations made by sectoral authorities dependent on or independent of the executive branch or by the authorities of a political subdivision of a country. In the "common law" countries, the term also includes the decisions of judges. In various other countries the customary law also has the force of a mandatory legal norm. In Moslem countries, laws consist of interpretations of divine revelations to the Prophet. 20/ It should be noted, however, that not all legal norms have the same weight and that some laws higher up in the legal hierarchy provide the framework for others. 21/

14. The category and type of norm that may be established by each governmental body should be determined with great care, particularly where legislative powers can be delegated. In many countries, judges have the power to review legislative acts to determine whether they are consistent with the basic legal framework within which the legislature (parliaments or executive branches) must work, and, if such is not the case, the correct interpretation and the final acceptance of such legislation usually consumes a great deal of time and money in costly litigations, thus slowing down the progress of needed development.

15. Experience shows how desirable it is in this regard, for the administrative branch - particularly at the technical level - to be given explicit authority, within a well-defined framework, to translate into regulations the general norms adopted at the parliamentary level. This system promotes flexibility, facilitates the implementation of legislation and makes allowance for regional differences and the incorporation of new technology.

16. The participation of the general public - and particularly water users - in the planning and legislative processes, as well as in certain aspects of water administration, has been recommended in various forums, including Valencia and Caracas 22/; in some countries, the point has been reached where such participation is considered a subjective right, the exercise of which should be protected. In addition to the means of indirect participation available through the political machinery of popular representation (parliaments, parties, etc.), the sectoral interests of water users, as well as those of persons who, without being users, are affected by water regulations (for example, dealers in agricultural produce or people who live in flood plains but are not water users), should be afforded legal guarantees and means of representation. There is a trend in this direction, which, in some countries, has its roots in long-standing tradition.

17. This participation can be accorded both to individual and to organizations representing groups of users. With respect to the latter, the most frequently used

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20/ See Dante A. Caponera, Water Laws in Moslem Countries. FAO, Irrigation and Drainage Paper No. 20, 1973.

21/ See document referred to in foot-note 5, p. 1.

22/ Caracas 11, 15 (c), 28, 36; Valencia 8.

method is to organize the user groups on the basis of the distribution systems or networks. 23/ It should be noted that traditions cannot be established by law and that getting consumers accustomed to participating actively in this type of organization is no simple matter. It cannot be achieved instantaneously by means of legislative magic but requires education or the introduction of agricultural extension and demonstration methods. Some laws provide for the compulsory organization of user associations or guilds.

18. The right of participation accorded to users and other interested persons enables them, first of all, to defend their individual interests where these are apt to be endangered by the various procedures established by the law in water-rights matters. The representation of group interests is customarily recognized in the following situations: (1) by means of public hearings at the water-policy decision-making stage prior to the adoption of legislation; (2) in the administratio of water-distribution systems, which, under some systems of law, is entrusted entirely to the users, particularly at the final stages of distribution, at an obvious saving in costs; (3) in the bona fide administration of justice in water matters, which, in some regions, is also entirely or partially the responsibility of judges or arbitrators who are themselves users and are elected by their fellow users.

4. Content of water laws: incomplete laws

Degree of government intervention decisive

19. Since, in almost all countries, water legislation has been passed on a piecemeal basis to deal with certain hazards, community conflicts or specific uses (irrigation, domestic, energy, etc.), gaps generally remain, making the legislation less effective. Furthermore, laws in other fields (tax laws, labour legislation, public service legislation) often include provisions concerning water. Such legislation must be consolidated and the gaps must be filled, since, when faced with such gaps, administrators are frequently confused or even at a complete loss. It will therefore be useful to draw up a list of matters which ought to be dealt with in water laws.

20. From a functional point of view, water legislation should deal with the following categories of relationships: (1) person - person, that is to say, the relationship between individuals with respect to water; (2) person - water, that is, the rules imposed on users regarding the use of water, (3) government - person, that is, the rules governing the relationship between users and the public

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23/ See, in connexion with the Water Tribunal of Valencia, Spain, the document referred to in foot-note 3, vol. 9, p. 801; and, in general, Joaquín R. López, in Annales Juris Aquarum - I (Mendoza, 1968), p. 235; W. Derrick Sewell and Ian Burton, Perception and attitudes in resources management (Ottawa, 1971).

administration with respect to water; (4) within the Government, that is, the rules governing the adoption and implementation of the water policies which are to be followed by the various bodies and civil servants. Within this range of relationships, water legislation, if it is to be complete, ought to deal with the matters listed in the following paragraph.

21. Effective water legislation should include at least the following topics:

A. Definition of national objectives with respect to water (water policies) and the means for achieving them. 24/

B. Gathering of information. Duties of both individuals and public bodies in this respect.

C. Control and ownership of water (public, private, "res nullius", riparian rights, etc.). 25/

D. Means of acquiring water rights (action of the law, concession, licence, registration, etc.).

E. Restrictions, that is to say, prohibitions affecting certain sources or uses of water.

F. Priorities as between regions, uses and users and in relation to other natural resources.

G. Conditions of use (domestic, municipal, crops, livestock, energy, industrial, mining and petroleum extraction, fish breeding, transport, recreational):

1. Quantity and availability;

2. Quality; 26/

3. Protection of property, natural resources and the environment; 27/

4. Payment in money or in kind;

5. Emergencies (droughts, floods, pollution, fire);

24/ See para. 10 above.

25/ See para. 61 below.

26/ See paras. 41 and 66 below.

27/ See para. 41 below.

6. Engineering works and projects relating to water (construction and operation), including the approval of new technological procedures and developments;

7. Re-use.

H. Legal régime affecting other persons and their property with respect to water use:

1. Easements, restrictions on control and expropriation of private property;

2. Obligations of non-users of water with respect to water.

I. Protection against harmful effects of water (floods, erosion, pollution etc.).

J. Judicial aspects of water. 28/

K. Participation of users and other interested persons in water administration. 29/

L. Water resources administration. Responsibilities and duties of various bodies. 30/

M. Special arrangements for certain categories of water:

1. Underground; 31/

2. Atmospheric; 32/

3. Coastal and estuary; 33/

4. Medicinal and thermal.

N. Registration and classification of waters, water uses and water rights. 34/

O. Evaluation and approval of new techniques for water use.

28/ See para. 34 below.

29/ See paras. 16-18 above.

30/ See paras. 49-51 below.

31/ See paras. 25-26 below.

32/ See paras. 25-26 below.

33/ See paras. 25 below, and Caracas 27.

34/ See para. 63 below.

It was recommended at Caracas 35/ that water legislation should encompass all activities contributing to the rational conservation, development and utilization of water resources, in terms of quantity, quality and the relationship between water and other natural resources or environmental factors.

22. Historically, water was originally used in the service or private interests and through private initiative, without the help of public works and without government intervention. At that stage, private enterprise was supreme and unrestricted. This is still the case in many places where the system of riparian rights or privately-owned water prevails. Governments began to intervene in water administration - and this should be noted, since the degree of State intervention determines the content, scope and range of water legislation - when the demand for water began to exceed the supply (according to the existing state of technology) and when disputes among consumers made government intervention necessary. Another factor which fostered intervention was the size and complexity of the hydraulic works needed to satisfy the steadily increasing demand which was beginning to tax the limit of individual capabilities. A third factor was the advent of statist and socialist political philosophies, not only with respect to the degree of economic and political centralization but also with respect to changes in the systems of land and water tenure. Finally, another factor was simply the natural expansion of State activities because of population growth and technological progress. In many countries today (for example, Colombia and Venezuela), there exist side by side areas in which hydraulic works and water services are administered directly by the Government and areas where the system of riparian rights or privately-owned water excludes any real possibility of government intervention. At times, the two systems may even apply to a single river. This makes it difficult to administer all the water resources of a country in a comprehensive and integrated manner.

23. Establishing a suitable boundary between the State sphere and the private sphere in the matter of water resources poses delicate problems which require a well-balanced solution. While it is true that in many cases the scale of hydraulic works and water services overtaxes the abilities of the private sector, it is also true that the spirit of private enterprise continues to provide the driving power behind economic development, even in socialist countries. A possible solution would be to allow private enterprise to play a role in the final stages of water distribution and utilization, while the Government would increasingly dominate and even monopolize the preliminary phases of planning, policy-making and the construction and operation of large projects. In any case, the law should establish the boundary and should guarantee that it will not be encroached upon by either side. It was recommended at Caracas 36/ that the water plan should be linked to water legislation and that its implementation should be mandatory.

35/ Caracas 33, 22, 41, 12.

36/ Caracas 17, 18.

24. It must also be borne in mind that individual or group interests - sectoral or regional - do not always coincide with the national public interest (that of the country as a whole). While the views of the former must be duly heard and considered, the decisions taken must be based on the national interest.

5. The hydrological cycle and the consolidation of water laws relating to the various water environments

25. At both Valencia and Caracas, 37/ it was recommended that the law should deal with water from the standpoint of the physical unity of the hydrological cycle, which constantly repeats itself as water passes through the following physical states: water on land, ground water, the oceans and atmospheric water. Various consequences flow from this legal concept:

(a) Equal treatment and management, under the law, of surface water, ground water and atmospheric water; 38/

(b) Elimination of the various legally-defined categories of water (for example, publicly-owned water, privately-owned water and ground water), which give rise to different legal régimes for each type of water. It was stated at Caracas that water should be viewed as a single entity in so far as the régime governing its ownership is concerned. What would vary would be the régimes governing its uses;

(c) Unification and consolidation, as proposed at Valencia, of the law governing fresh water and the law governing maritime water, 39/ the boundaries between the two being increasingly more difficult to establish, particularly as regards coastal waters and estuaries 40/ and as regards the problem of marine pollution by effluents originating on land.

26. The hydrological cycle is a law of nature which the laws of man can neither ignore nor contradict. Only very recently (in Colombia, Israel and Peru) have laws provided that surface, ground and atmospheric waters should be administered jointly inasmuch as these three physical states of water are merely different stages of the hydrological cycle and any tampering by man with water in any one of these states will affect the other states. The same consideration applies to substantive legislation. For example, there is less and less justification for

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37/ Caracas 1; Valencia 1.

38/ Caracas 16 (b); Valencia 5.

39/ See document referred to in foot-note 10, p. 3.

40/ Caracas 27; and W. R. Derrick Sewell, Planning challenges in the management of coastal zone water resources, in document referred to in foot-note 3, vol. 14.

water law to treat naturally-flowing ground water any differently than water which is drawn from the ground by human effort, since the utilization and conservation problems are similar in both cases. Legislation on artificial rainfall must necessarily have an impact on the availability of surface water and on the legal régime governing such water. Surface-water pollution may extend to nearby ground water, and water law must accordingly take this fact into account. This problem was considered at Caracas. 41/ This integrated approach in the case of water law as recommended at Caracas may entail solutions such as the following: (a) the right to utilize water should be granted to an individual on the basis of national priorities and of his previously determined individual requirements, irrespective of the source 42/ of supply (surface water, ground water, rain or snow), so that when a person receives water from one source he cannot receive the same amount from another source; (b) in certain areas (places where aquifers are being recharged) only surface-water use should be permitted, while elsewhere only the use of ground water should be allowed; (c) there should be an obligation to recharge aquifers with excess or already utilized surface water; 43/ (d) in areas where there is sufficient rainfall, the use of surface water for irrigation should be prohibited.

6. Are codes the answer? Changes in legislation

27. As used here, the word "code" means much more than a mere compilation. 44/ It means the functional integration of all the legal norms relating to water in a single body of law in order to facilitate their proper consultation, understanding and interpretation by those for whom they are intended, namely, the users, the rest of the population and the authorities responsible for applying them. Because legal texts are scattered throughout many different bodies of law - as so often happens in this field - the legislation frequently is ineffective. At the functional level, to "integrate" norms in a code also means that they must be headed by a set of general principles which can be applied to resolve unforeseen individual cases in accordance with a particular methodology.

At Valencia, 45/ the "need for a systematic body of laws" was emphasized. At Caracas, 46/ codification on the scale just described was explicitly recommended. The question which serves as the heading for this chapter becomes a purely semantic

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41/ Caracas 16 (a).

42/ Caracas 5.

43/ Caracas 16 (b).

44/ See document referred to in foot-note 5, p. 1; and Cano, op. cit., in foot-note 7. In the latter document, the subject is considered in greater detail.

45/ Valencia 4.

46/ Caracas 7.

one, since the problem lies much more in the content and scope of the legislation than in what name it is given.

28. The constant need to alter water-use priorities and to ensure that legislation covers new technologies can be met only by the frequent revision and amendment of water laws. The very fact of proposing codification implies introducing changes in the legal régime. The need for a revision at this stage, in order to bring legislation into line with national objectives, was recommended at Caracas. 47/ As any revision carries with it the possibility of interfering with acquired rights, particular caution is imperative, especially where farmers are concerned. It also makes sense when dealing with acquired rights to distinguish between cases in which inherited rights actually are infringed and others in which only expectations are frustrated, without there being any actual loss or gain. One writer has stated 48/ that today it is more important to reallocate water rights than to allocate them. At Caracas, it was recommended 49/ that when altering legislation, "considerable attention should be devoted to the elaboration of transitional provisions permitting a change-over from the old system to the new system and that, in addition, the new precepts should be applied immediately". It was also stated that a generic change in the legal designation of a particular category of water (for example, the transfer of ground water from private to public ownership) "does not imply that compensation must be paid in respect of an existing situation, since to alter the legal system does not constitute expropriation."

47/ Caracas 12.

48/ Radosevich, op. cit., in foot-note 3, p. 23.

49/ Caracas 8, 31.

7. Legislative methodology

29. The ECAFE document mentioned in foot-note 5 represents an excellent methodological exercise which should be extended to other regions.

30. The first task facing anyone planning to draft water legislation is to take an inventory of the legal provisions concerning water which are incorporated in existing legislation and are generally scattered throughout many bodies of law, not all of which relate to water matters. The mere act of preparing a systematic index of the legislation (federal and provincial) in force in his country led the author to fill 260 pages of a book. 50/ After an inventory of the legislation has been drawn up, the legislation must be classified and evaluated in the light of the constitutional context, its consistency with the water policy which has been adopted, and the effectiveness of its implementation. With regard to the further stages of the process, the author draws attention to the document mentioned in foot-note 7, in which he provided a detailed exposition of the methodology followed in the preparation of the Renewable Natural Resources and Environmental Protection Code, promulgated by Colombia in 1974. This methodology is valid, mutatis mutandi, for water legislation, especially as the legal régime governing water was covered in that code. The reader is also referred to a summary review by the author on the same subject. 51/

31. The Caracas Conference made a number of methodological recommendations which suggest that water legislation should:

(a) include the establishment of priorities, taking into account, inter alia, the social, economic, political and physical factors; 52/

(b) be flexible, i.e., easily adaptable to changing circumstances or geographical variations; 53/

(c) integrate norms relating to the control of quantity (volume used) with those relating to the preservation of quality; 54/

50/ Economic Commission for Latin America and Consejo Federal de Inversiones Los recursos hidráulicos de Argentina /water resources of Argentina/ (Buenos Aires, 1969), vol. 7, p. 269-529.

51/ G. Cano, Comprehensive environmental legislation: a summary review of Colombia's Environmental Code, in Environmental Policy and Law (Lausanne, 1976), vol. 1, No. 4, p. 177; Metodología para la legislación integrada sobre el ambiente humano y los recursos naturales /Methodology for integrated legislation on the human environment and natural resources/ (Santiago, Chile, 1976), FAO, document RLAT 801/76/24 (also in English).

52/ Caracas 3; Valencia 3.

53/ Caracas 12; Valencia 4.

54/ Caracas 42; Valencia 6.

(d) be integrated with legislation relating to other natural resources, treating them as a single unit in view of their interdependence; 55/

(e) take into account the relevant socio-economic and ecological studies, 56/ as well as hydrological studies in the case of legislation on ground water; 57/

(f) define and regulate the administrative structure responsible for applying the legislation; 58/

(g) be preceded by methodological studies that will make it possible to define and to make a selection from among the various legislative techniques available; 59/

(h) provide ways and means for evaluating new technologies and embody norms to encourage their adoption, provided that they are socially and economically acceptable; 60/

(i) provide for a determination of the environmental impact of water utilization, including atmospheric water, and stipulate the right of individuals to have recourse to the courts in order to compel the administration to make such a determination. 61/

8. Negative aspects of water legislation

32. It would be useful to consider briefly the reasons why many existing water laws, far from promoting the optimum use of water, have become obstacles to doing so.

A. UNCERTAINTY AND INSECURITY

33. The uncertainty derives, firstly - and this happens often - from the difficulty of ascertaining what legislation is in force or from the discovery that the legislation contains contradictory provisions. See paragraph 30 above.

34. The insecurity may have a physical cause, or it may be rooted in the law. In the first case, it is necessary for the law to offer security, both bolstering the

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55/ Caracas 20, 22, 2, 12, 41, 27.

56/ Caracas 15 (f).

57/ Caracas 16 (a).

58/ Caracas 24, 33.

59/ Caracas 26.

60/ Caracas 29; Valencia 7.

61/ Caracas 43 (b) and (f).

user's conviction that he will receive the required quantity of water at the appropriate time and assuring him that he will be protected against disasters (such as floods). The user will feel that he can rely on his water supply if the law is fair, and if he believes in its efficient, timely and proper application - if, for example, he is convinced of the efficacy of prompt judicial action in matters relating to water. The certainty of being protected against disasters will depend on the measures imposed by law and observed by the administration - for example, those guaranteeing the stability of hydraulic works and the proper functioning of alarm systems and systems for the prevention and immediate repair of damage.

35. Insecurity rooted in the law derives from the user's lack of conviction that the rules of the game will not be altered to his detriment. This does not mean that such rules should be weak, but, rather, that they should be followed and observed. Nor does it mean that they should be immutable, but, rather, that if a change does become necessary, it will not infringe any traditional rights. This implies that the system of compensation, when compensation is due, must be applied fairly and swiftly, for if legislative changes or changes in individual status are to be made at the expense of the traditional rights of the individual existing by virtue of a promise of legal security conferred by the law, then such security will vanish, and the interest and initiative of the individual will be destroyed. Legal reforms should include provisions for the prompt and fair settlement of the compensation claims to which they give rise.

Another component of legal security is the belief in effective judicial protection against possible arbitrariness on the part of the administration with respect both to the allocation of water rights and to supervision over their proper use.

B. RIGIDITY

36. The inflexibility of water law can be regarded as due to circumstances of both time and place. Inflexibility as regards time may be attributable to the fact that legislation becomes obsolete when it is not brought up to date to reflect changes required by technological progress or other factors. For example, it was pointed out at the Valencia Conference (1975) that some countries drafted their water laws at a time when water was exploited through diversion projects that did not utilize storage facilities; consequently, it was the low water level of the rivers that limited and determined the amount of water rights to be allocated. However, after storage works were built, the quantity of water which could be distributed increased or was spaced over time, thus requiring the adoption of new legal principles to deal with the new situation.

In some areas, particularly those which tend to be arid, at a time when the amount of water available exceeded the demand, the laws were designed to promote its increased use, whereas when the situation was reversed, the laws also had to be changed - although in some countries they were not - in the direction of limiting and controlling the consumption of water, as well as conserving it.

Legislation on flood-plain management has recently made its appearance, and necessarily so, as population pressures have given impetus to settlement in the flood plains, but there are some countries in this situation which have not yet adopted such legislation.

37. In countries comprised of regions having different climatic or physiographic characteristics, the law should permit the adoption of different solutions for the various situations. For example, the priorities of water use cannot be identical for a region where the annual rainfall is 3 metres and for one where it is only 100 millimetres.

38. The question of the flexibility of the law was also discussed at Caracas, 62/ and it was suggested that the law should adjust consumption in relation to periods of scarcity or to inefficient use.

39. The legislator drafting water laws should strive to ensure that the legislation is flexible as regards both categories of the problems just mentioned. One way to attain this goal is to include in the law only basic general principles which, by means of regulations, can be developed in different ways depending on the place of application or in the light of changing circumstances. As regards the relevant recommendations made at Caracas, reference is made to foot-note 53 above.

C. LACK OF COMPLETENESS

40. This was considered above, in paragraphs 19 to 21, and is mentioned again here out of concern for methodology.

D. LACK OF FUNCTIONAL CO-ORDINATION. INTEGRATION WITH NATURAL RESOURCES AND ENVIRONMENTAL LEGISLATION

41. In order to be effective, water legislation must be integrated both functionally and territorially. 63/ The latter aspect is dealt with in the following subsection. As far as functional or intersectoral integration is concerned, stress must be laid on the need to harmonize water legislation with the legislation in other closely related or overlapping sectors of activity and with a country's over-all policy. For example, it is not at all uncommon to find that standards for the prevention of water pollution set by departments responsible for public health differ from or even contradict those set by the department responsible for water management. Water legislation must be harmonized with legislation

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62/ Caracas 19.

63/ See Documents of the United Nations Interregional Seminar on Integrated Utilization of Water Resources, Fergana, USSR, 1966 (document ST/TAO/SER.C/144), and, in particular, Institutional and Legal Aspects of Integrated Water Resource Management, (United Nations publication, Sales No. E.70.II.A.4).

concerning taxes, labour, credit, land tenure, public health and urban, industrial, 64/ power-generation and mining development, etc., and the respective policies must also be harmonized. Within the sphere of water legislation itself, the norms regulating the quantity of water used must be harmonized with those regulating the quality of the water. In this connexion, see paragraph 31 (c). As to the legal régime for coastal and estuary waters and its harmonization with the régime governing other resources in those same areas, see foot-note 40 above. At Caracas, 65/ a specific recommendation was made concerning the functional co-ordination of both administration and legislation.

42. The National Renewable Natural Resources and Environmental Protection Code, promulgated by Colombia on 18 December 1974, constitutes the first attempt to deal in a comprehensive and integrated manner with a legal régime for natural resources - including water - and other environmental elements based on the physical interdependence of those resources and elements. See the documents of the regional Latin American meeting organized by FAO at Bogotá (July 1976) to discuss this subject. 66/ The Caracas Conference formulated various recommendations regarding the desirability of such legislative integration, 67/ which is advisable when a country reaches the degree of institutional advancement justifying such integration.

E. LACK OF TERRITORIAL INTEGRATION: INTER-JURISDICTIONAL PROBLEMS

43. This is becoming the vexata quaestio of water development, both nationally and internationally, and water legislation and law must provide a solution for it.

Hydrographic basins are delimited by the watersheds, and they neither recognize nor respect artificial political divisions drawn by man. This occurs on both the national and the international planes, which we shall now examine:

(i) National

44. This problem arises mainly - though not exclusively - in federal countries. In such countries the question is to establish the legal régime for inter-State, interprovincial, intercantonal or interrepublic (as in the case of the federated republics of the USSR and Yugoslavia) rivers and basins. No attempt will be made here to deal with the administration of these basins but only with the legal principles that should govern their utilization. The first problem is to decide which organ of a country's political structure is empowered to lay down the relevant norms. In some countries these may be established only by means

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64/ Caracas 43 (c).

65/ Caracas 39.

66/ See foot-notes 7 and 51 above; also G. Cano, Introducción al derecho y administración ambientales y de los recursos naturales /Introduction to environmental and natural resources law and administration/ reprinted from the Revista Javeriana (Bogotá, 1974) Nos. 414-416; and A legal and institutional framework for natural resources management (Rome, 1975) FAO Legislative Studies No. 9.

67/ Caracas 2, 12, 20, 22, 41.

of contractual agreements (such as "compacts" or interprovincial treaties), whereas in other countries only the central parliament or, in some cases, the highest court of justice is vested with this power. The second problem is to decide who is authorized to apply or enforce the norms. The third problem is what are the legal bases 68/ for such legal regulations. In non-federal countries the question may arise among the various territorial departments, municipalities or communes which share the same river basin. The ideal would be to adopt a single legal régime for all the jurisdictions involved (whether in the form of a treaty, "compact", legal decision or arbitral award). Failing that, parallel legislation might be attempted or the simultaneous standardization of legislation through unilateral action. This has been recommended as a first step to deal with the problem of water-pollution control in cases where various countries or political jurisdictions are involved and no agreement can be reached.

A fairly common solution has been to create ad hoc authorities or bodies for the administration of basins and to assign to them powers for certain well-defined matters which are ordinarily the responsibility of the regular government ministries or departments. Such bodies may be empowered to apply the general water legislation of the country, or they may be given ius edicendi, in other words, the authority to issue regulatory norms. 69/

45. The question of the transfer of water between basins is also related to this problem particularly when the basins are situated in different political jurisdictions. The law must establish the criteria and procedures for authorizing such transfers, with provision for all the parties concerned to be heard. Relevant criteria were recommended at Caracas. 70/

(ii) International

46. As regards the legal aspects of the problem of international basins and other international water resources, whether surface or underground, the first step towards a solution is, of course, the conclusion of treaties between the Governments concerned. When the conclusion of such treaties proves impossible, or when differing or conflicting interests are at stake, it is necessary to rely on the rules relating to international watercourses or, in the absence of such rules, on the general principles of the relevant law. Various non-governmental bodies have

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68/ Centro de Economía, Legislación y Administración del Agua /Centre for Water Economy, Legislation and Management/, Seminario de administración de cuencas interjurisdiccionales /Seminar on management of interjurisdictional basins/ (Mendoza, Argentina, 1975), document CELA/De/R.1/5/75.

69/ See Systems of administrative organization for the integrated development of river basins, United Nations document E/CN.12/503 (1959); and Integrated river basin development (United Nations publication, Sales No. E.70.II.A.4, New York, 1970); see also document referred to in foot-note 71 below, p. 40.

70/ Caracas 21; see para. 70 below.

been active in defining such rules and principles, and this work is continuing. 71/ The General Assembly of the United Nations 72/ has adopted various resolutions on the exchange of information and consultations in this field. It has also urged the International Law Commission to embark on the task of codifying the law of the non-navigational uses of international watercourses, and the Commission has been devoting itself to that task. The United Nations Environment Programme has also been entrusted with responsibility in this field in so far as environmental matters 73/ are concerned.

A recent United Nations publication, which is based on the work of a Panel of Experts, 74/ outlines the activities thus far accomplished in this field and treats the legal aspects of the development of international water resources as distinct from the law relating to international watercourses. Among the recommendations of that panel, are the following:

> Appropriate international rules pertinent to the utilization and development of international (non-maritime) water resources should be adopted under the auspices of the United Nations, preferably in the form of a general convention. The Panel felt certain that in the preparation of such rules the work already accomplished in this field by other bodies such as the Institute of International Law, the Inter-American Bar Association and the International Law Association, including the Helsinki Rules on the Uses of the Waters of International Rivers, would prove to be of much relevance and assistance.

In the Americas region, the Inter-American Juridical Committee and the Inter-American Bar Association - both of which are affiliated with the Organization of American States - have prepared a draft inter-American river convention which is to be considered by a special Inter-American conference. Although the holding of this conference has been agreed upon, no specific date for it has as yet been determined. 75/

In the African region, the Commission of Jurists of the Organization of African Unity recommended the adoption of the principles of the Helsinki Rules.

47. The above-mentioned General Assembly resolutions have served to define a legal doctrine in regard to two matters: the exchange of information and the principle of consultation between countries sharing the same international hydrographic basin. The principle of consultation would apply where a work planned by one country might cause considerable harm to another country in the same basin or to the

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71/ See Management of international water resources: institutional and legal aspects, annexes II and III, (United Nations publication, Sales No. E.75.II.A.2, New York, 1975).

72/ General Assembly resolutions 1401 (XIV), 2926 (XXVII), 3071 (XXVIII), 2669 (XXV), 3129 (XXVIII) and 3281 (XXIX).

73/ General Assembly resolution 3129 (XXVIII); UNEP resolutions UNEP/GC/26, UNEP/GC/44/III and UNEP/GC/55, and UNEP decisions 18 (II) and 44.

74/ See document referred to in foot-note 71.

75/ Organization of American States, Draft Inter-American River Convention (Washington, 1965).

international community. Principle 21 of the Stockholm Declaration covers all natural resources - including water resources - and is therefore applicable to the influence of other kinds of natural-resource management on water management and vice versa. Recommendations 51 to 55 of the Stockholm Conference relate to the practical consequences arising from the application of this principle. 76/

48. The Caracas Conference recommended that international organizations should support the establishment of appropriate legal régimes for international water resources; 77/ it supported the need to codify the law relating to international watercourses; 78/ and it recommended that the International Law Commission should expedite the work of codification and should consider the legal principles recommended by the Conference for application at the national level, particularly those principles relating to the interdependence of the different kinds of natural resources. 79/ In so far as Governments sharing international basins, including ground-water basins, are concerned, the Conference also made the following recommendations: 80/

(a) Efforts should be made to establish agreements embodying the basic common principles of planning;

(b) Co-operative machinery should be established between the countries concerned and should provide for: (i) non-discrimination in the search for solutions to the problems of pollution and other harmful influences, and in ensuring free access to justice for all concerned; and (ii) the exchange of information between the States concerned as regards projects and activities which might result in pollution or have other harmful effects in another State;

(c) In view of the fact that the complete benefits to be gained from international water resources are greater where co-operative arrangements exist between the countries concerned, those countries should: (i) seek ways and means of establishing and improving international co-operation - among the countries sharing the basin - through the establishment of appropriate administrative and legal machinery, bearing in mind the principle of limited territorial sovereignty over international water resources; (ii) give attention to improving the machinery for the settlement of disputes in cases where the countries sharing a basin have difficulty in reaching agreement; and (iii) encourage universities and scientific institutions to pay greater heed to social-science research in the areas of public administration, politics, science, law and economics in so far as the specific problems of international water-resource management are concerned.

76/ Report of the United Nations Conference on the Human Environment, (United Nations publication, Sales No. E.73.II.A.14, New York, 1973).

77/ Caracas 40 (a).

78/ Caracas 49.

79/ Caracas 50 and foot-note 72 above.

80/ Caracas 52, 15 (f), 16 (a).

F. FAULTY ADMINISTRATIVE CO-ORDINATION

49. There is a well-known proverb which states that the road to hell is paved with good intentions. Excellent legislation can fail if the system established for its implementation is inadequate. The fault lies with the manner in which the administrative machinery is organized. For example, in a given country, enforcement of the law for the abatement of water pollution is entrusted to the mayors of the various towns. The legal norms are good, but the mayors are only human and have political interests - for instance, they want to attract more industry to their cities because this means a higher employment rate and higher tax returns. The result is that the mayors compete with one another to see who can be most lenient in applying the legislation because that will bring in more taxes and provide more employment in their area. The same thing can occur among nations which have agreed to apply a common legal régime for the prevention of pollution in order to avoid price competition in regard to manufactured goods (the cost of such goods will naturally be lower in the countries which are less strict about the quality of their industrial effluents).

50. Inefficient implementation of the law on the part of the administration may be due to various factors: the most recently mentioned (deliberate lack of will), lack of internal co-ordination, shortage of staff or of sufficiently trained staff, lack of proper equipment, and lack of awareness of the objectives of the legislation. The legislator must take all these matters into account and must not confine himself to adopting legal texts.

51. At Valencia, 81/ it was advocated that water management should be organized on a unified basis at the national, basin and community levels, that is, on a functional rather than a political basis. At Caracas, it was recommended that water law should make provision for: 82/

(a) An administrative structure responsible for defining a water policy and controlling the use of water;

(b) A systematic concept of administration, embracing all the activities with which administration is concerned;

(c) Centralized planning for the entire basin or water management area, while entrusting the operational aspects to bodies or agencies responsible for the various uses or sectors, whether public or private;

(d) Adoption of the basin as the unit for water-resource management without prejudice to the existence of political and geographical management units (for example, economic development units) having jurisdiction over water resources extending beyond or not coinciding with the hydrographic basins;

(e) Avoidance of the proliferation of new administrative institutions;

(f) Interagency and intersectoral co-ordination and co-operation.

81/ Valencia 2.

82/ Caracas 14, 24, 33, 35, 38, 39.

G. USE-ORIENTED INSTEAD OF RESOURCE-ORIENTED

52. In general, it can be stated that, in respect of water legislation, the majority of countries have at some time passed through or are likely to pass through the following stages: 83/ (a) legislation oriented towards certain hazards deriving from the existence or use of water or water run-off (regulations on flood control, natural run-off of rain-water, or construction of wells in urban areas); (b) legislation oriented towards particular uses of water (laws on the supply of potable water, irrigation, fish-breeding or river navigation); (c) legislation oriented towards multiple uses of water and conservation of water as a resource, such legislation being concerned primarily with water and the co-ordination of its uses and secondarily with the particular uses themselves; (d) legislation oriented towards the joint management of various natural resources, which takes into account and regulates the interdependence of water and other natural resources (legislation dealing simultaneously with water, soils and forests, etc.); (e) legislation oriented towards the environment and dealing with water, other natural resources and other elements of the environment (for example, the Colombian Code on Renewable Natural Resources and Environmental Protection, 1974). This is not to say that environmental legislation should encompass all water legislation, since there are areas of the latter which do not necessarily find their place in environmental law.

Most countries are at stage (b), and this impairs the effectiveness of their water laws, owing to a lack of intersectoral co-ordination and to contradictions between the laws which regulate different water uses. The more modern systems of legislation are moving towards stage (c), that is to say, they are primarily oriented towards water as a resource, and the regulation of water uses is of secondary importance.

H. LACK OF REALISM

53. This subject has already been treated in paragraphs 4, 7 and 8 above, where it was stated that all water legislation should be adapted to the physical, economic and cultural circumstances prevailing at a given time in a given place. A few examples serve to illustrate this assertion:

(a) The laws in force in humid regions, where irrigation is not required and the principal use of water is for navigation, do not need to take water demand into account because of the surplus supply of water. Into this category fall the laws which established the system of riparian rights. When an attempt was made to extend this system to arid regions where the demand for water exceeded the supply - as occurred in the western part of the United States - the régime did not work and became ineffectual. The Reclamation Act (1907), by abandoning the system of riparian rights, helped to correct that defect.

83/ See document referred to in foot-note 66, pp. 3 and 18; United Nations, document E/4636/Add.1, article entitled: Law, institutions and natural resources.

(b) The prior appropriation system is suitable where the intention is to encourage greater use of water, that is to say, to accelerate water development. When, however, the demand for water begins to exceed the supply, it becomes necessary to control or restrict the use of water, and this system then becomes ineffective and, therefore, obsolete.

(c) A sophisticated system of water-use charges based on the volume of water consumed can function well and encourage efficient use in areas where the users have been properly educated and where the economy is sufficiently robust to absorb the cost of meter installation. When either of these circumstances is absent, however, the system fails to work, and its practical application simply lapses.

(d) A water law which, for purposes of conservation, allows ground water to be extracted only during prescribed hours or in limited hourly amounts is doomed to failure unless the cost of installing clock-type or volumetric meters can be borne by the users.

A law making irrigation by spray or trickle application techniques mandatory in areas where users have not received adequate technical training will also surely come to grief unless such training is provided, before the law comes into force.

(e) Where laws permitting the assignment of water rights on the basis of percentage quotas of stream flow have been enacted prior to the existence of storage works, they will need to be supplemented when such works are constructed because the system of assignment will have to be modified.

54. At Caracas, 84/ it was recommended that legislation should be framed solely in the light of the political, legal, economic and hydrological conditions prevailing in the region concerned, whether a country or a lesser area (basin, etc.)

I. ATTITUDE TOWARDS THE ADOPTION OF TECHNOLOGY

55. The Secretary-General's report 85/ warns against the hazards of adopting new technology without due reflection, a warning which is not meant to imply that there should be resistance to progress. Water laws should be sufficiently flexible to accommodate technological progress, as was indicated in paragraph 36 above. However, as was recommended at Valencia, 86/ such laws should be adopted only when they are suited to the social and economic climate of the times. To this should be added that technological considerations must also be taken into account; hence the Caracas recommendation 87/ that legislation should provide ways of assessing new technology before its application is approved.

84/ Caracas 40.

85/ See document referred to in foot-note 2.

86/ Valencia 7.

87/ Caracas 29.

J. FACTORS OF LEGAL OR CUSTOMARY ORIGIN HAMPERING THE DEVELOPMENT OF WATER RESOURCES

56. In some instances, the law has sanctioned certain religious or political traditions or customary practices which, although they may have been appropriate in the past, have become obsolete and are hampering the development of water resources. In Peru, for example, the derechos de cabecera accorded preferential rights to upstream users over downstream users, thus subjecting the latter to the arbitrary practices of the former. The 1969 water legislation reform, by abolishing such rights, eliminated this impediment to water-resources development.

57. Systems establishing different classes of rights, to be exercised simultaneously over the same waters, were adopted to encourage the development of water resources by favouring and protecting the earlier users in point of time over subsequent users. In cases where water demand increases and plantations or industries which, economically, are in the public interest have been built up under the protection of different categories of rights, it usually proves impossible to continue maintaining the old distinctions, since these now become factors impeding water development. In a ground-water basin in which 10,000 wells are operating, it would be impossible, without creating social turmoil, to attempt to limit the consumption of the newcomers in order to protect the older-established users.

58. The allotment of water for irrigation on the basis of units of irrigable area to be supplied with a maximum volume of water over a period of time encourages wastage rather than the most efficient use of water. It may also encourage the illegal or unauthorized use of the surplus water for areas other than the authorized areas.

59. Legislators should carefully examine both existing and potential factors impeding water development of the kind described - many more examples could be given - with a view to their elimination.

9. Prevailing trends in the modernization of water laws

60. As used in this context, the word "trends" means that certain recent legal reforms have begun to provide the solutions which this chapter is attempting to identify. Mention of these, however, should not obscure sight of what was said above in paragraphs 4, 7 and 8.

A. PUBLIC OWNERSHIP OF WATER AND INCREASED GOVERNMENT CONTROL

61. There is a marked and widespread trend towards increased government control over the management and use of all waters. This has taken various forms: incorporation of waters into the public domain; direct and undisguised government ownership; or simply ultimate State control, including control over the use of waters which the law defines as the private property of individuals. It was advocated at Caracas that all waters should be designated as public, 88/ being either communally owned and available for the use by all or, alternatively, being subject to ultimate State control.

B. ADMINISTRATIVE MANAGEMENT VERSUS JUDICIAL MANAGEMENT

62. In some countries - especially the common law countries - judges play an important part in assigning water rights, both to individuals and in resolving conflicts between public bodies. Their powers of control over management by the public administration are immense. At Caracas, however, it was advocated that the administration (the executive branch of government) should both grant water rights and impose servitudes, rights of way and other restrictions on the immovable property of third parties. 89/ It would seem that judges do not normally have direct access to the requisite technical and economic information or to comprehensive data permitting an over-all view of water development problems.

C. NECESSITY OF MAINTAINING A WATER RESOURCES INVENTORY AND A REGISTER OF WATER RIGHTS

63. Both these measures concern the problem of a Government's need to possess adequate information for the efficient management of water resources. In countries in which the use of certain waters by individuals without the requirement of governmental authorization is permitted by law, the Government does not know the identity of the users or how much water is being used. This happens with riparian rights and certain spring and ground waters. There is clearly a current trend towards making mandatory: the determination of water resources and the maintenance of a water-resources inventory; the registration of water-use rights (including privately-owned waters); and the supply of information on the amount and purpose of

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88/ Caracas 1, 14, 30.

89/ Caracas 5.

water use. At Caracas, it was recommended 90/ that the obligation to register water rights and to contribute towards the register and the inventory should be imposed by law.

D. WATER CHARGES AND TAXES

64. This subject is treated in another document, similar in its purpose to the present report. 91/ Suffice it to recall here that, in so far as legal considerations are concerned, it was recommended at Caracas 92/ that taxes should be imposed as a means of ensuring the efficient use of water and that water charges should be set as a means of apportioning the costs among users and of offering incentives to promote efficient use and deter wasteful practices and pollution.

E. ENVIRONMENTAL CONSERVATION VERSUS DEVELOPMENT

65. Since the Founex Report, 93/ it has become clear that environmental conservation is not incompatible with development and that in developing countries the latter is a prerequisite of the former. At Caracas, where the participants took this same view, it was recommended 94/ that: the law should ensure that the conservation of natural resources does not hamper development; development and environmental protection should go hand in hand in hand so that a favourable ecological balance is maintained; and the use of water resources should be co-ordinated with pollution control.

F. HE WHO POLLUTES MUST PAY

66. It was recommended at Valencia and Caracas 95/ that this economic principle should become a rule of law and be incorporated in legislation, as has already been done in the case of a number of modern laws.

G. ATTACK HARMFUL EFFECTS AT THEIR SOURCE

67. It was advocated at Caracas that the law should deal first with the causes of the harmful effects of water, 96/ especially those deriving from floods and soil

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90/ Caracas 5, 13 (c).

91/ Caracas, Warford.

92/ Caracas 5, 37.

93/ Development and Environment (Founex, 1971); see document A/CONF.48/10.

94/ Caracas 6, 13 (f), 42; Valencia 6.

95/ Valencia 6; Caracas 9, 43 (c).

96/ Caracas 9, 13 (e).

erosion, and subsequently attempt to control such effects. This matter is closely related to what was said in paragraphs 41 and 42 above concerning the integration of water legislation with the legislation on other natural resources, especially flora, fauna and soil, including their international aspects. 97/

H. THE BASIN AS THE UNIT OF WATER MANAGEMENT. WATER TRANSFERS

68. Adoption of the hydrographic basin, not only as a unit of administrative water management, but also as an object of legislation, was the subject of several of the recommendations made at Caracas. 98/ However, it was stated at Caracas that, for purposes other than water development, such as economic or social development, it may be desirable to have a broader geographical unit of administrative management than the basin itself, or to include all or part of a number of basins, because the political and administrative structure of a country should not be turned into a "federation of basin authorities".

69. A water bill for Argentina 99/ attempts a legal definition of the term "basin" which takes into account the situation where the area of a surface basin and that of a subterranean basin do not coincide.

70. Transfer of water resources between basins was also a topic of discussion at Caracas, 100/ the legal régime governing such transfers being important in international as well as domestic law, as evidenced by the case of Lake Lanoux. Adoption of the following general legal principles was advocated at Caracas: firstly, that transfers should not give rise to irreversible long-term imbalances in the regions concerned, and, secondly, that full satisfaction of all the developmental requirements of the basin supplying the water should be ensured.

I. DETERMINATION OF PRESENT AND PROSPECTIVE USES

71. There has been a gradual evolutionary trend in laws away from those which recognized the private ownership of water, and allowed owners or concessionaires to use it as they pleased towards laws which define permissible water use and even, in extreme cases, which authorize, for example, the use of water for growing certain crops but not others. It was proposed at Caracas 101/ that water development plans approved by law should specify the purposes for which water may be used in the light of its availability, and should do so on the basis of forecasts made within the framework of sectoral policies and the over-all development policy.

97/ Principle 21 of the Stockholm Declaration (1972); see International Law Association, Report on the 53rd Conference - Buenos Aires (London 1968, p. 531).

98/ Caracas 14, 32, 34.

99/ G. J. Cano, Anteproyecto de legislación nacional de aguas /Preliminary draft of national water legislation/ (Buenos Aires, 1972) p. 7, articles 3 to 5.

100/ Caracas 21.

101/ Caracas 23.

J. LEGISLATION ON FLOOD PLAINS, EROSION, SALINITY AND POLLUTION

72. As these are all factors in environmental deterioration, it was recommended at Caracas that water legislation should make adequate provision for preventing or mitigating them, 102/ especially as regards areas having a fragile ecological balance.

K. ORGANIZATION OF INFORMATION

73. The documentation for item 1 of the agenda of the Conference demonstrates in itself the importance of possessing adequate information in the field of water management. While such information relates primarily to hydrometeorology, it also concerns: cartography, geology, the quantitative aspects of water use, water quality, economic considerations (costs), social considerations (population sectors supplied with water), ecological impact and legal matters (ownership or possession of water rights). Legislation can - and in the case of some modern laws does - require users to supply information on the type, the adequacy and even the cost of water supply. The use of meters as a source of information may also be imposed by legislation.

74. A particular aspect of this problem, which the legislation or the law should provide means for resolving, is the intergovernmental relationship, whether as between the political subdivisions of a federal State or as between sovereign States at the international level. In respect of the latter, see paragraphs 46 to 48 above. The Colombian Environmental Code referred to in paragraph 42 above (article 10 (a) and (b) and articles 20 to 24) deals with this matter both domestically and internationally and is significant in the latter regard because of the unilateral adoption, through domestic legislation, of standards which are internationally binding on the Government enacting the legislation.

10. Water legislation as a policy instrument in other areas

75. As was stated in paragraphs 11 and 41, neither water legislation nor water policy constitute ends in themselves; rather, they should be regarded simply as integral parts of a broader whole, namely, a country's over-all policy for the achievement of national goals. That being so, water policy, together with water legislation, may be and often is used for purposes unrelated to water as such. For example, its function may be to: influence the location and size of urban or rural human settlements by withholding or providing water supply; promote the integration of different regions of a country by providing for the diversion of water from water-surplus to water-deficit areas by means of water grids or interbasin transfers; influence land-distribution and land-tenure patterns in arid and semi-arid areas where there can be no land reform without water reform; implement a zoning policy by providing or failing to provide water in conformity with the policy objectives; influence food production by granting priority to the agricultural sector over others in the use of water; or implement an environmental policy.

102/ Caracas 43 (c) and (e).

11. Conclusions

76. It was not intended that this paper should contain recommendations, since the participants in the Mar del Plata Conference will no doubt wish to extract and formulate these for themselves.

It should be borne in mind that the Valencia "considerations" and the Caracas recommendations represent the essence of the many working papers presented at those two forums. More than 100 documents, totalling over 1,500 printed pages assembled in 17 volumes, were discussed at Caracas. These figures are given to highlight the fact that the 52 recommendations referred to throughout this paper represent the distilled thinking of many extremely highly qualified water experts from all parts of the world. Both the Caracas and the Valencia Conferences brought together for completely free discussions participants from North and South and from East and West.

This monograph is intended as a methodological aid for those who propose to embark on the task of adopting water legislation or brining it up to date. Its purpose is similar to that of the ECAFE document referred to in foot-note 5, and it does not claim to offer specific recommendations for any particular problem. An attempt has been made (chap. 8) to identify the factors which have caused many existing water laws to be ineffective or to constitute bottle-necks, and an account has been given in some detail (chap. 9) of the prevailing trends in the modernization of water laws. Thus, the reader may, if he so desires, draw his own conclusions and make his own recommendations in the light of the circumstances in his own country. The international organizations, for their part, may wish to consider the recommendations addressed specifically to them by the Caracas Conference. 103/

103/ Caracas 48 to 51.

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NON-CONVENTIONAL WATER RESOURCES: SOME ADVANCES IN THEIR DEVELOPMENT

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INTRODUCTION

A rapidly growing world population, increasingly scarce natural resources and a rising standard of living have all contributed to an increase in the demand for water. This, in turn, has led to the need to supply more water than existing sources can provide in many already settled areas and, in addition, has produced demands in areas where, formerly, settlements either did not exist or were severely limited. The era of "free" or inexpensive water is rapidly coming to an end in many locations.

The growing scarcity of water has led to the investigation of ways to increase the available supply. These include more efficient utilization of existing resources, selective use of water of varying quality, and the tapping of non-conventional water resources. This paper summarizes some of the advances in the use of non-conventional water resources.

When one considers all possible non-conventional water resources, water can be thought of as an unlimited resource in comparison with other natural resources such as land, energy and raw materials. Given foreseeable technological progress, the location of human settlements and their level of economic activity need no longer be dictated by the availability of conventional water resources. Non-conventional water resources can be defined as water made available for human use by planned intervention in the chemical or physical phenomena of the hydrological cycle using non-conventional techniques. In some cases this intervention accelerates or decelerates the natural processes, e.g., cloud seeding, evaporation suppression, phreatophyte removal and glacier tapping. In other cases, the intervention is an imitation of a natural process in a closed or controlled system, e.g., desalination or waste-water reclamation. Still other non-conventional resources have been considered, such as long-distance hauling of water by supertankers or the even more exotic concept of transportation of icebergs from arctic regions.

These latter non-conventional resources involve systems which deliver water from one location to meet a demand elsewhere. The long history of the development of non-conventional water resources, i.e., the supply of water by techniques considered revolutionary for their time, has centred on the delivery of water from its natural source to centres of population. Water supply and drainage systems, while conventional to us, must certainly have been non-conventional 5,000 years ago when first introduced in the Indus Valley of India, as must have been the first rockfill dam built about the same time by the Egyptians. Long-distance conveyance of water, conventional even to the Romans, was certainly considered non-conventional before the construction of large water supply adequaducts by King Solomon of Israel in the tenth century B.C. The same is true of the development of ground water in both confined and unconfined aquifers in the Fertile Crescent, the most impressive of which, the Ghanat system of the ancient Persians, is still operational in modern Iran. Various water-pumping devices (whether powered by humans, animals or water in ancient times, by Leonardo da Vinci's pumping inventions, by steam, internal combustion, or electric-powered pumps of the modern era), have all broadened the concept of conventional water resources.

Water resources are exploited for many purposes. It is possible to divide these into three major categories - domestic (life-sustaining), agricultural and industrial (economic inputs), and recreational. The former two are consumptive, the latter is not. Because of the special effort and considerable cost involved in supplying non-conventional water resources, it is crucial to evaluate the ultimate use of this water. The supplying of water for life-sustaining needs requires a different justification from that for the supplying of water for economic or recreational activities. For production inputs, the feasibility of exploitation of these resources depends on economic justification.

In most places and in most instances, the marginal cost of producing water by non-conventional techniques exceeds the marginal product value of the water. Because many of the more promising techniques - desalination, for example - are energy intensive, the end of the era of "cheap energy" will greatly affect their development and exploitation. Yet, just as the scarcity and pricing of energy resources have led to intensive development of non-conventional sources (such as off-shore drilling, gasification of coal, nuclear and solar power), parallel economic forces are acting as catalysts in the water resources sector. What once seemed impossible or unfeasible is slowly becoming merely non-conventional and will later become conventional.

Man's relentless effort to discover and develop the means to overcome natural constraints is producing results in the water resources sector. The following discussion is a brief description of the progress made in developing some of these non-conventional water resources.

DESALINATION

Introduction and recent history

Many projects have been proposed for solving the sea-water desalination problem. The greatest in scale and detail were the joint American-Israeli project for a nuclear dual-purpose plant designed in 1964 by Kaiser Engineering and the Catalytic Construction Company, and the Bolsa Island project planned for the Los Angeles vicinity, which was also planned as a nuclear plant producing both water and electricity. Neither project materialized owing to financial problems also, shortages in the United States of America did not become as acute as had been predicted. Today, the largest desalination markets in the world are in the Middle East, although many plants exist in Florida, California, Texas and other parts of the world.

The history of modern desalination technology is characterized by the following landmarks:

Multi-effect submerged tube evaporators, used in power plants and ships since the nineteenth century.

The vapour compression (VC) process, used commercially since the early twentieth century.

The invention by Silver of the multistage flash (MSF) evaporator in the early 1940s.

The foundation of the United States Office of Saline Water (OSW) in the late 1950s.

The incorporation by Loeb and Sorirajan of cellulose acetate membranes in the reverse osmosis (RO) process in the early 1960s.

The invention of fluted tubes and the incorporation of these tubes and other revolutionary design concepts in commercial-size, multi-effect distillation (MED) plants in the late 1960s.

The invention by the Du Pont Company of hollow fibre nylon membranes in the early 1970s.

Perhaps the greatest single stimulus in the field of desalination so far has been the Unites States Office of Saline Water. This Office of the Department of the Interior has spent hundreds of millions of dollars during its more than 10 years of existence on investigations of every practicable desalination process. Research projects included the operation of several commercial-size pilot plants. Notable successes, which resulted in fully scaled-up commercial desalination plants, were achieved with MSF (San Diego), MED (Freeport), VC (Roswell, New Mexico), and RO (Wrightsville Beach, North Carolina). The OSW also published numerous research and development progress reports and financed many laboratory experiments.

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In 1973, OSW was closed and the United States desalination research budget drastically reduced. The functions of OSW were then taken over by the newly formed Office of Water Research and Technology (OWRT) of the Department of the Interior. Its desalination research and development activities today involve primarily the development of RO for large-scale and, possibly, sea-water desalination (operation of Wrightsville Test Station and the design of the Yuma project), combined MSD and MSF sea-water desalination and sewage water reclamation (Orange County project), co-operation with the State of Israel in developing low steam pressure distillation using the horizontal aluminium tube multi-effect (ATME) process (Ashdod dual-purpose project), and some research into the freezing process.

Many other companies and governmental authorities, such as the UKAEC in the United Kingdom, the French Atomic Energy Commission, Israel, Iran, Kuwait and Saudi Arabia are involved today in research on and the design and operation of desalination plants. The cost of water desalted today by thermal processes, which account for most of the current desalting capacity, varies from $3 to $5 per 1,000 U.S. gallons.

Description of desalination processes

A. Multistage flash distillation

In flash evaporators, a large stream of brine is heated in stages as it flows inside copper alloy tubes. In the last stage, the brine is heated by steam supplied from an external source such as a boiler or a power plant exhaust. The brine is then admitted into flash chambers in which, as pressure is reduced from stage to stage, a small proportion of the brine is evaporated. The vapours pass through demisters and condense on the outside of the copper alloy tubes while, at the same time, they heat the brine. The condensate is collected in the product trays and, while accumulating, becomes the desalted water stream. At the cold end, part or all of the brine is blown down. The rest is recycled while being blended with chemically treated and de-aerated make-up brine.

Today, MSF designs vary with respect to the following aspects:

Flow connexions may be once-through or provide for recycling, the former required high pretreatment costs;

The mechanical and structural design may have either long tubes or cross tubes which are more expensive to install and require more pumping power but are more easily cleaned mechanically and allow for the isolation of leaking tubes and easier maintenance in the long run. Other mechanical and structural design variations include one-storey vessels *versus* two-storey vessels and cylindrical vessels *versus* rectangular vessels;

The water treatment system may provide for acid addition (H_2SO_4 or HCl) or polyphosphate or poly-electrolyte addition. The non-acidic means prevent serious corrosion problems but are more costly because they require frequent periodic shutdowns for cleaning with mild acid and are limited in use at 160°-200° F. They also sometimes cause foaming problems.

Construction materials include carbon-steel water boxes either coated with epoxy resins, rubber or fibreglass, or clad with stainless steel or copper alloys; tubes may be of aluminium brass or copper nickel; pump casings, shafts and impellers may be of cast iron, stainless steel, copper, nickel or titanium alloys.

Current trends indicate the use of acid treatment with de-aeration and strict pH control, and the cladding in stainless steel of any steel surface which is in contact with hot acidic brine. The trend is to build huge plants, most of which are dual-purpose and automatically controlled.

Plants using the MSF process account for more than two thirds of the world's total installed desalination capacity, making MSF the most widely accepted large-scale sea-water desalination process. Typical plants erected recently are the 48 (6 modules x 8 each) plant in Lok on Pai, Hong Kong and the 13.5 plant (largest module:9) belonging to Societe Italiana Resine in Sardinia, Italy.

The limiting factors in MSF design are the large volume of huge vacuum-tight vessels needed, the flow per unit width of the flash orifices, and the limited permissible range of top brine temperatures, which cannot be too high (over 250° F) or too low (below 170° F). Serious corrosion problems tend to occur in plants operating five years or more. A plant in Key West, Florida, was closed recently due to high energy costs and serious corrosion problems.

B. Multi-effect distillation

In the MED process, the heating steam is condensed on one side of the first effect tube bundle while a comparable amount of steam is evaporated at slightly lower pressure from the brine flowing on the other side of the tubes. This evaporated steam is then used as the heating steam in the next effect. Thus, the condensate flow in the first effect is multiplied by approximately the total number of effects. Research in MED has recently resulted in some revolutionary design concepts. One partitioned vessel is used instead of separate vessels for each effect. Fluted, instead of plain, tubes are used.

Today, MED evaporators vary in the following respects:

The process flow sheet may have either backward feed with brine preheating or forward feed, the latter being simpler but making for less efficient use of energy;

The mechanical design may have either vertical or horizontal tubes, the latter design being limited in heat fluxes and condensate drain but having a simpler steam flow pattern. The design may also call for separate vessels or one partitioned vessel, fluted tubes or plain tubes which have a much lower heat transfer co-efficient but less severe scaling problems and downflow or upflow, which requires fewer pumps;

The construction materials may provide for either CuNi, AlBr, titanium, or aluminium tubes, the last being the cheapest but limited to temperatures up to 160° F. Other construction material problems are the same as for MSF and vary according to temperatures and water treatment methods

The water treatment methods are similar to those for MSF, except that this process allows for lower maximum brine or steam temperatures and, thus, for the use of non-acidizing water treatment system with less serious corrosion problems. A seeding process for scale prevention is also being studied.

The MED process ranks second to the MSF process with respect to installed capacity and technological acceptance. Modern plants use backward feed with a flash-like preheating system and aluminium brass double fluted tubes. Other advanced concepts are being developed now in France, Israel and the United Kingdom which utilize low-cost horizontal aluminium tubes and perhaps low-temperature steam. Typical MED plants are the Gibralter 0.4 plant with AlBr fluted tubes, the St. Croix 2.2 plant with AlBr fluted tubes, the Eilat 1 plant with aluminium horizontal tubes, and the Shevchenko 13.5 plant.

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The most serious limiting factors in MED are the need to preserve the high heat transfer coefficients of new fluted tubes which tend to deteriorate due to scaling. In horizontal aluminium plants, the problem is to obtain sufficiently high coefficients. Other problems are similar to those of MSF.

C. Vapour compression

In this process, feed water is introduced into a vessel under vacuum conditions. The water vapour is compressed by a mechanical compressor to one side of the tube bundle, where it condenses and gives up its latent heat to the vapour extracted from the brine feed. The latent heat of evaporation is consequently supplied by the condensing vapour. This process does not require a cooling water supply.

Vapour compression plants vary in the following respects:

Process conditions: There are moderate vacuum plants and extreme vacuum plants which require less feed water pretreatment and preheating and have fewer corrosion problems. However, extreme vacuum requires higher volumetric capacities of the compressor, tighter vacuum vessels, and leak-proof shaft seals. The source of energy may be an electrical or diesel motor. The latter requires more maintenance but also allows for the use of its cooling water for feed preheating and is, therefore, practical for remote sites with no electricity supply.

The mechanical design may call for either centrifugal compressors or roots-type compressors, the former being more difficult to design and less efficient but also requiring fewer shaft bearings and seals they are, thus, more reliable. Other design variations include horizontal versus vertical tubes, natural circulation versus forced circulation which has higher heat transfer coefficients but requires additional pumps, vapours in the tube side versus vapours in the shell side, and preheaters of plate type versus preheaters of shell and tube type.

The construction materials may provide for vapour compressor blades of titanium or inconel and for tubes made of aluminium versus AlBr or CuNi.

The water treatment methods may require no treatment at all, polyphosphate addition or acid addition, depending on the temperatures (vacuum levels).

The VC process still requires verification of its reliability. Some modern plants proved to be very reliable in the initial years of operation and needed a minimum of maintenance and fuel. Modern plants use extreme vacuum conditions, forced circulation, minimum water treatment, and employ centrifugal compressors. One modern plant with a capacity of 0.16, built by Israel Desalination Engineers, is located in the Canary Islands. The maximum capacity of VC per unit is 0.2-0.3. Many such plants operate in Israel, the Persian Gulf area and the Canary Islands.

The most serious limiting factors of this process are found in the volumetric capacity, the efficiency, the compression ratio, and the reliability of the compressors which restrict the capacity per unit.

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D. Reverse osmosis

In the reverse osmosis process, the treated feed water is compressed and passes under high pressure (400-800 psi) through a semi-permeable plastic membrane which rejects 90-95 per cent of the salts.

Reverse osmosis plants differ in the following respects:

The process parameters of maximum concentration ratio or extraction ratio vary depending on the salinity of the feed water.

The pressure level may range from 400 psi to 1,500 psi for sea-water RO plants;

There may be one stage or two stages for sea water.

The mechanical design may call for one of the three types of membrane configuration commercially available today:

(a) Tubular modules which require minimum pretreatment and are easily cleaned but are not efficiently packed give large module volumes per unit area of membrane.

(b) Spirally wound membranes which are better packed need more pretreatment than tubular modules

(c) Hollow fibre nylon membranes produced by Du Pont or those made of cellulose triacetate by Dow are packed best but have the lowest fluxes and are most sensitive to feed-water turbidity and other types of contamination

Pretreatment, the extent of which depends on the quality of the feed water. Pretreatment usually requires at least two stages of filtering and softening, one stage of ion exchange or other means to remove iron and manganese traces, pH control by addition of acid, and chlorination to prevent biological attacks on the membranes.

Present commercial RO plants desalt brackish water containing 2,500-6,000 ppm TDS. Full-scale field testing with various feed waters is now in progress. Hundreds of plants have been installed in the past five years. Some modules are used to treat tap water in hospitals and electronics plants. This process is considered to be the most promising because of its extremely low energy requirements and its simplicity. The OWRT is involved in the feasibility study of a large RO plant at Yuma. Mekoroth, the Israel Water Company, after several years of testing RO modules in Eilat, decided to build a 0.5 plant for desalting brackish water in the Israeli desert. Du Pont is developing its PERMASEP module for sea-water desalination, while other manufacturers are doing so for their own modules. A large, typical plant is the Ocean Reef, Florida 0.6 plant. One limiting factor in the RO process is the rejection ratio which today is close to 95 per cent of the salts per stage. Another restricting factor is the fluxes which are low. Manufacturers of RO modules today (including Du Pont, Dow, UOP and Ajax) guarantee

not more than 20-30 per cent of flux deterioration at the end of the three-year lifetime of their membranes. Membranes, especially those of cellulose acetate, are also sensitive to biological attack and to traces of metal which may be found in the feed water. The short expected lifetime of membranes, the low fluxes and the poor salt rejection ratio are the most detrimental factors which research must aim at improving.

E. Solar distillation

In this process, the water is fed into a pool which is covered with plastic or glass. Due to solar radiation, part of the brine evaporates and condenses on the inner side of the cover while the heat is removed by the surrounding air.

This process is employed to a very limited extent in remote locations. It requires a minimum of moving parts and almost no energy. The Governments of Mexico and Chile plan to use this process in some locations.

The most serious limiting factors here are the water production per unit area of the pool, which is 2-4 litres/m^2/day of the pool area, and the high investment per unit of water production ($60/$m^3$/year).

Choice of a desalination process

The selection of a deslination process depends upon factors such as operating experience and technological acceptance, capacity required, salinity of feed water, reliability required and access to skilled maintenance personnel, specific fuel demand and type of energy supply available and specific investment per unit capacity. Tables 1, 2 and 3 summarize these considerations.

Dual-purpose plants

Thermal distillation processes are scaled-up, in contrast with vapour compression, and can desalt sea water, as contrasted to reverse osmosis and electrodialysis, but they need two to 10 times as much energy per unit of water production. On the other hand, these processes use "low-grade" thermal energy. Indeed, they cannot use steam at higher than 260° F saturation temperature due to sulfate scaling limits. The energy required to produce steam varies only slightly with its pressure. Therefore, it is possible to produce high-pressure steam, to let it produce electricity while it expands (from 2,000 psi in a fossil plant and ~1,000 psi in a nuclear plant), and to use it as 20-30 psi or even 5 psi for desalination. A normal condensing power plant condenses its steam by cooling water at 1.5"-3.5" HgAbs (0.7-1.7 psi). When coupled to a desalination plant, it has to condense the steam at a higher pressure and a portion of its power is lost.

The cost of energy contained in one ton of steam increases from zero at 1.5"-3.5" HgAbs to a maximum cost of $2x$10^6$ BTU = $4.4/tons of steam at maximum pressures (1,000-2,000 psi). This corresponds to a primary fuel cost of $80/ton.

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Table 1. Present-day desalination installations

	Flash evaporator	Multi-effect evaporator	Vapour compression	Reverse osmosis	Electro-dialysis	Solar distillation
Operating experience	Has been used for decades; capacity increased largely in the past 10 years.	Has been used for decades in the form of a submerged tube evaporator; present concepts evolved in the past 5-10 years.	Has been used for decades; modern compressors improve performance.	Number of plants increased largely in the past 3 years.	Used wherever feed water quality permits.	Used in very remote locations (Australia, Mexico, Chile).
Capacity per unit	Largest single unit: 9 mgd	Largest single unit: 2.2 mgd	0.2 mgd	1.4 mgd 0.015 mgd/module	5 mgd	
Salinity	Sea water	Sea water	Sea water	Brackish water up to 2 500-6 000 TDS	Brackish water up to 2 000 TDS	Sea and brackish water
Reliability	Reliable due to its simplicity. However, production deteriorates with time as a result of scale deposits and corrosion problems. Plants that use acid need water box cladding and pH control.	High-temperature plants: the same as MSF. Low-temperature plants: may use cheaper materials (aluminium tubes) and a cheaper pretreatment method.	Plants recently installed are very reliable.	Process may be very reliable due to its simplicity. Its reliability is subject to field tests with respect to membrane lifetime, salt rejection properties, flux, and response to feed water quality.		

Table 2: Specific energy demand and investment a/

	Unit	Multistage flash	Multi-effect distillation	Vapour compression	Reverse osmosis b/	Solar distillation
Specific output	(lb product water/ 1 000 BTU)	8-12	8-12	20	110	
Specific energy demand:						
Low-grade heat	(Kcal/m^3)	55 000	55 000			
Heat equivalent of electric power c/	(Kcal/m^3)	5 200	3 900	31 000	5 200	
Total heat requirement	(Kcal/1 000 U.S. gal.)	227 500	222 600	117 200	19 700	
Fuel consumption d/	(kg fuel/m^3	6	5.8	3-4	0.5	
	(kg fuel/1 000 U.S. gal.)	22.8	22.1	11.3	1.8	
Specific investment:						
including site development and energy source	($/$m^3$/year)	2-3	2-3	3-5	0.8-1.2	30-60
	($/1 000 U.S. gal. day)	3-4.5	3-4.5	4-7	1.1-1.7	40-80

Note: 1 m^3 of water = 265 U.S. gallons.

a/ For the largest module existing in 1975.

b/ For brackish water only.

c/ Assuming a power generation thermal efficiency of 33 per cent.

d/ Based upon bunker fuel oil.

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Table 3. Water cost

	Unit	Multistage flash	Multi-effect distillation	Vapour compression	Reverse osmosis a/	Solar distillation
Energy at $80/ton of fuel	$/m^3	0.48	0.46	0.26	0.04	
	$/1 000 U.S. gal.	1.81	1.74	1.06	0.15	
Fixed charges at 10 per cent/ year and capacity factor 0.8	$/m^3	0.32	0.32	0.50	0.12	5.0
	$/1 000 U.S. gal.	1.20	1.20	1.90	0.45	
Operation and maintenance staff	$/m^3	0.05	0.05	0.12	0.10	
	$/1 000 U.S. gal.	0.19	0.19	0.45	0.38	
Membrane replacement or chemical pretreatment	$/m^3	0.15	0.15	0.15	0.18	
	$/1 000 U.S. gal.	0.57	0.57	0.57	0.68	
Total	$/m^3	1.00	0.98	1.05	0.44	5.0
		3.78	3.70	3.98	1.66	

Note: 1 m^3 of water = 265 U.S. gallons.

a/ Brackish water.

Since the energy requirements of thermal desalting processes today are twice as high as those of sea-water RO plants, they will compete with the latter only when the relative energy cost becomes one half of the primary energy. This can be achieved at a temperature of about 250°-260° F.

Summary and future prospects

Progress in desalination technology in the past decade was less than hoped for but more than had been expected. The developments of MED with double fluted vertical tubes or horizontal aluminium tubes and the breakthrough in RO were big steps forward. The cost (C_W) of product water, excluding site development, overhead and pretreatment, is comprised of energy expenses and expenses proportional to the specific investment, which usually decreases with specific energy demand. Thermal processes may be optimized so as to make these expenses approximately equal by optimizing the temperature drop per effect in MED and the vacuum level (pressure) in VC.

The over-all result is that the product water cost is a geometric mean of the energy cost (C_E) and the investment cost (C_C) (construction material and annual fixed charges), multiplied by some factor which depends on the specific process and units: $C_W = \sqrt{C_E \cdot C_C}$. Otherwise stated: the water cost is approximately proportional to the optimal specific energy cost per unit water production. In a thermal process which produces 10 lb of product water per 1 lb of steam, this is = 10 lb/1,000 BTU = 10 tons of water/ton of steam. The limit to the cost of 1 lb of water is thus 20 per cent of the cost of 1,000 BTU, or the cost of 1 m^3 of water is 20 per cent of the cost of 1 ton of steam. Adding some allowance for operation and maintenance, it is concluded that the limit to the cost of 1 m^3 of water cannot be lower than 20-30 per cent of the cost of 1 ton of steam. The cost of steam in a dual-purpose plant at the exhaust of a back pressure turbine may be 30-50 per cent of the cost of primary steam. Thus, the cost of 1 m^3 of desalted water in a dual-purpose plant may be as low as 15 per cent of the cost of the fuel required to produce 1 ton of steam.

In the RO process, the greater part of the water cost is due to the high price, low productivity, and short life of the membrane. Therefore, developments in this process might be expected to be along the lines of reducing investment costs by increasing pressures and related fluxes. There will also be research into cheap membranes with high fluxes and high salt rejection.

Another desirable breakthrough would be some kind of ion exchanger that could be regenerated by cheap chemicals. Future advances in desalination technology will probably also be seen in the use of dual-purpose plants to reduce energy costs. Larger plants will reduce site development costs, overhead, and operation costs per unit of water. There will also be research into cheap corrosion resistant materials and high heat transfer coefficients for distillation plants.

RENOVATION OF WASTE WATER

Introduction

Water is used as a means of transporting pollutants. In water-short areas, however, it is uneconomical to throw away 999 tons of water to dispose of 1 ton of pollutants. This is the basic motivation for waste-water reclamation - the preservation and recycling of the water used to transport pollutants.

Water has always been used and reused by man. Cities draw water from surface streams and lakes and discharge wastes into the same streams and lakes, which in turn become the water supply for downstream users. In the past, dilution and natural purification were usually sufficient to allow such a system to be satisfactory. In recent years, however, population and industrial growth have made it evident that waste water must be treated before its discharge into bodies of fresh water in order to maintain their quality.

To ensure the exploitation of waste-water potential, it is necessary to develop an integrated approach to the disposal of waste water to prevent ecological pollution while allowing for the possibility of reuse. This requires the adaptation of techniques and methodology which will integrate treatment, disposal and reuse processes.

In Israel where all the known fresh-water resources have been developed, the new decade will be a transition period in which large-scale waste-water reclamation projects will be initiated and will increase in proportion to domestic consumption. The reclaimed water will then become the main additional source of water, providing a substitute for water drawn from agricultural consumption in order to meet domestic demand. The water management will have to be adjusted for the absorption of water of varying quality within the consumption balance.

Historical background

The use of sewage effluents began long before today's complex technology of treatment systems was developed. Waste-water application to the land was recorded by the ancient Greeks in Athens. The use of effluents for farmland irrigation was first reported in sixteenth century Germany. From there the concept of the application of sewage effluents to farmland spread throughout continental Europe and England, and then to South Africa, Australia and Mexico, as those areas were colonized by Europeans.

The use of sewage effluents for irrigation in the United States began in the late nineteenth century. Ground-water recharge projects started in the early twentieth century in the semi-arid regions of California and Utah. With the passing of time, the crude sewage farms of the early 1900s have been replaced for the most part by managed farms on which treated waste water is used for growing crops, for landscape irrigation, and for ground-water recharge.

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In Israel waste-water renovation is relatively new. In 1956 a plan was drawn up for the reuse of effluents as an additional water resource. This policy has been reflected in the increasing utilization of this resource.

Table 4 summarizes the results of a survey carried out in 1967 on waste-water reuse in Israel. It will be noted that the utilization rate of waste water produced in rural communities is higher than that produced in urban centres. This situation will be substantially changed during the next decade when plans for the reuse of waste water originating in urban areas, especially the Dan (Tel Aviv) region and the Kishon (Haifa) area, are expected to be implemented.

Table 4. Reuse of waste water in Israel

Source of waste water	Amount produced (m^3/day)	Amount reused (m^3/day)	Percentage reused on daily basis	Amount reused (millions of m^3/yr)
Urban areas	343,000	79,000	23	20.6
Rural settlements	64,000	42,000	65	8.5
Total	407,000	121,000	30	29.1

Technology

The challenge of reclamation projects is not so much to develop advanced treatment technologies, since many already exist; it is rather to choose and adapt these existing techniques to ensure that suitable effluents are provided to meet specific demands for the required quality and at minimum cost. Sewage treatment must be more advanced for reclamation than for disposal purposes. In recent years, new technologies have been introduced and found to improve the quality of biologically treated effluent. These include chemical oxidation, coagulation, floatation, absorption, ion exchange, ultra-filtration. While these processes are efficient, they present problems of monitoring, control and reliability. These difficulties stem from the fact that the techniques were developed to overcome specific problems and not to reach target qualities.

The selection of the proper sequence of treatment processes requires:

A characterization of the quality of the waste water;

A definition of the target quality required;

The formulation of alternative treatment processes;

An economic evaluation.

The possible types of use for reclaimed waste water are:

Restricted irrigation (for field crops);

Unrestricted irrigation and recreation;

Industrial use;

Artificial recharge of aquifer (for indirect supply);

Direct water supply.

To reach the quality requirements for the above uses, the following sequences of treatment are usually practised:

(a) For restricted agricultural irrigation use, the basic methods of secondary treatment, biological flocculation and oxidation are employed. Under Israeli conditions, the activated sludge process and biological filtration (trickling filter) are not extensively used. More common are the stabilization ponds in which the waste water, which may or may not have received some preliminary treatment, is retained in a pond or lagoon for a period of up to several weeks. These ponds have the advantage of providing a fairly high degree of treatment at low cost with little need for equipment or skilled operators. As a consequence, these ponds are more suitable for small communities where land is not costly and odour nuisances are more manageable.

In large communities in Israel, the use of aerated lagoons followed by polishing ponds (secondary sedimentation) is becoming an established practice. The effluent leaving the aerated lagoons has a relatively high concentration of suspended solids (200 mg/l) which is reduced to about 30 mg/l in the polishing ponds. This process is not widely used in other parts of the world. However, the results obtained to date from the first plants in Israel are promising;

(b) For unrestricted agricultural use it is essential to remove nitrogen from the effluent or to nitrificate it by continuing the process beyond the biological treatment. For this use disinfection is also required. A high BOD removal is necessary. In this context, the incorporation of nitrification-denitrification within the biological treatment has been proposed and is now being tested;

(c) For industrial cooling use, in addition to the biological treatment, chemical - usually lime - treatment is required to reduce phosphate, alkali, ammonia and detergent;

(d) For ground-water recharge, nitrogen removal and chemical coagulation are compulsory beyond the biological treatment. The effluent quality should approach that of potable water. Additional quality improvement is achieved during passage through the soil profile. The renovated water should be chlorinated before distribution;

(e) For direct use, the specified drinking water quality is required. Furthermore, in the treatment process, potential polluting elements not specifically detailed in the standards are also removed. This could be achieved by the use of a chemical coagulation treatment with active carbon filtration and disinfection.

Economics

The total cost estimates of treatment are usually based on the following indicators: biological load as BOD, surface detention time and sludge handling. A cost estimate for a plant in Israel with a capacity of 20,000 m^3/day is presented in table 5.

Table 5. Summary of costs for a 20,000 m^3/day treatment plant a/

(January 1976 prices)

Type of use	Investments b/ (millions of Israeli pounds)	Annual costs (investment plus O and M) (Israeli pounds per cubic metre)
a. Restricted agricultural use	5.8-6.1	0.29-0.35
b. Unrestricted agricultural use	19.7-24.1	0.89-1.27
c. Industrial use	26.6-36.3	1.19-1.66
d. Ground-water recharge	30.0-39.8	0.98-1.89
e. Direct use	46.9-56.3	1.83-2.37

a/ Israeli pounds are converted to dollars at a rate of approximately £I 10 = $1.

b/ Excluding land cost.

It is worth while to note that the cost of basic treatment (usually exceeding the level of type-a use) cannot be justifiably charged directly to a user of reclaimed water. Thus, the water charges should, in this case, include any additional treatment plus the regular conveyance and storage charges.

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Future directions

Some new treatment approaches are currently being considered.

Among the treatment processes discussed, the nitrification-denitrification process is essential if the effluent is directed to type-b use above. New developments have shown that this process can be incorporated into the existing biological treatment at relatively low additional cost. It is, therefore, worth while to encourage its further development.

The possibility of advancing the chemical treatment to the biological treatment stage is being investigated. If proven successful this will lower the cost of effluent purification for high-quality use (type-c) by about 25 per cent.

One of the key issues in waste-water treatment is the problem of sludge treatment and disposal, since this influences the economics of waste water reclamation. As the reclamation processes become more widespread, the problem of sludge handling becomes more acute, because of the larger quantities involved. Furthermore, the conventional sludge removal methods are of environmental concern. Also, the introduction of chemical treatment produces chemical sludges that are difficult to dispose of. Consideration should be given to the possibilities of sludge reuse and regeneration.

The reuse of reclaimed waste water for irrigation requires some seasonal storage facilities. Storage of reclaimed waste water, unlike that of conventional water, may be a source of environmental deterioration.

Before reclamation can be widely practised, there are a few questions to be resolved. These include the problems of salt and organic accumulation and the effect of bacteria and viruses on the environment - soil, ground water, vegetation and animal life. Also, the subjects of conveyance and storage of effluents are not well documented and further research is needed before large-scale reclamation projects can be carried out.

Dan region reclamation project

Undoubtedly the most ambitious project for waste-water reuse in Israel is that concerning the Dan region, the metropolitan area of Tel Aviv. The Dan region has the highest concentration of the nation's population. In 1995 the population of the region is projected to reach 1.3 million people, who will consume 144 million m^3/yr of water and produce 115 million m^3/yr of waste water. This waste water was considered a viable national water resource as far back as the 1950s and methods for its reclamation which combine both environmental enhancement and augmentation of water supply have been sought.

The combined project for purification and reclamation, as formulated in the 1960s, foresaw a gradual development of a project for the collection and conveyance of the sewage to the Sorek dunes. After purification in lagoons, the

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effluent was to be recharged by spreading basins into the local aquifer; the renovated water, after being blended with fresh water, would then be pumped and delivered for general use, including drinking. The original waste-water reclamation project for the Dan region was formulated in 1962. Since then some conceptual changes and design modifications have been made. One such change resulted from the increased alternative value of land in the region, thus substantially increasing the cost of the original project. Another resulted from the stricter standards which were formulated for the quality of renovated water, making the originally proposed treatment unsatisfactory.

At present the somewhat modified original project is operational, treating some 15 million m^3/yr. Under consideration for the second stage of the Dan region project are two alternative designs. They differ in the uses planned for the water.

The first is a modified (lower rate) biological treatment plant (MBT) with combined BOD and nitrogen removal, to produce effluents for unrestricted use in agriculture (type-b use). The MBT comprises treatment of the screened, degritted sewage in a single-stage, internally recirculated reactor, wherein removal of carbonaceous BOD could take place concurrently with successive oxidation of nitrogenous compounds to nitrates and reduction of the nitrogent gas discharged to the atmosphere.

The second is a conventional (activated sludge) biological treatment plant with BOD removal without full nitrification to produce effluents for restricted agricultural use (type-a).

Either effluent has to be stored during the rainy season, when agricultural consumption is at its lowest level. As in the original plan, underground seasonal storage in the local aquifer under hydraulic and hydrologic control is considered for type-b quality. This method, however, is not practicable for type-a quality effluents, mainly because of the presence of ammonia and nitrates.

The investment, at 1976 prices, for the first alternative is estimated to be as follows:

	Millions of Israeli pounds
Treatment plant and additional treatment for 120 million m^3/yr	464
Recharge facilities	37
Pumping system	78
Regional network for drinking supply	45
Network within the settlements	39
Total	663

Construction time is estimated to be 4.5 years.

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The total annual cost is estimated as £I 1.34/m^3 of which £I 0.84 is for treatment, £I 0.38 for recharge and pumping and £I 0.12 for distribution.

For the second alternative it is assumed that the total output of the Dan regional effluents can be utilized in the arid south of Israel as part of the existing agricultural quotas for restricted use only. This plan, because of the lower quality of the effluents, also requires a new separate conveyance network consisting of a pipeline 50 kilometres long and 70 inches in diameter, one pumping station, above-ground storage facilities and a distribution system to the irrigation fields. Separate regional and individual supply networks will also be needed to bring drinking water to 40 settlements. Some engineering and environmental problems concerning storage and conveyance of such effluents are still to be resolved.

The estimated investment, at 1976 prices, in this project are:

	Millions of Israeli pounds
Treatment and additional treatment for 110 million m^3/year	426
Conveyance network	246
Above-ground storage	40
Regional networks for drinking supply	45
Networks within the settlements	39
Total	796

Construction time is estimated to be 5.5 years.

The annual cost is estimated to be £I 1.67/m^3 of which £I 0.85 is for treatment and £I 0.82 for water conveyance and distribution.

The Dan region reclamation project is recognized as an ambitious and costly undertaking, but its implementation is vital to Israeli development. To ensure successful operation of this complex project, an extensive programme of research, including jar tests, berch-scales and pilot plants, is being carried out. A monitoring system for the quality of the reclaimed water is envisaged during operation of the plant.

Concluding remarks

Water reclamation and reuse are at present the most economical solution to water shortages. Adequate precautions, however, should be taken in the design and operation of these systems to protect the well-being of the community. This presents no insurmountable technical problems, although more knowledge will lead to more efficient and more reliable solutions.

Water supply, waste disposal and water reuse are inextricably interrelated activities, usually affecting more than one population group and several geographical areas. Where applicable, the establishment of regional multipurpose authorities having control of both water resources and water treatment may be the best solution to the management of these activities.

In principle, water uses should be graded according to the degree of purity required, and the available water sources should be allocated in such a way that water of high quality is not used for a purpose that can tolerate a lesser degree of purity.

ARTIFICIAL RAINFALL STIMULATION

Background

Man's attempts at rain-making have progressed from a long history of strange rituals through pseudo-scientific experiments to the present stage of concentrated scientific effort. This effort has led to a comprehensive understanding of the phenomena of cloud physics and the processes leading to precipitation. The progress made supports the thesis that artificial rain stimulation is a feasible method of augmenting rainfull. Research has yielded techniques to determine how and when to intervene in the natural atmospheric phenomena to increase precipitation. Progress has been hampered, however, by the overwhelming complexity of atmospheric phenomena and their variability in time and space. The assessment of the effects of any intervention is currently possible only by the use of statistical methods. One need only consider the reliability of weather forecasts to appreciate the difficulty of analysing weather modification experiments.

The first step in the scientific effort at rainfall augmentation has been to understand the physics of precipitation formation. The degree to which the effects of artificial intervention in natural processes can be controlled so that they act with or against those natural processes depends on our precise knowledge of those natural mechanisms which we wish to modify and an appreciation of the extent to which conditions for such intervention exist.

Rain formation processes

The process which creates rain is the growth or conversion of very small cloud droplets to much larger precipitation elements. A typical cloud element is about 10μ in diameter and a typical raindrop about one millimetre. About one million cloud droplets constitute one raindrop. The embryo of a precipitation particle is a cloud particle of about 100μ in diameter. The existence of such elements in sufficient concentrations in the cloud is a necessary condition for an efficient rain-forming mechanism. The two processes which can operate to cause this growth are the "all water" process and the "cold"

process. The all water, or condensation-collision-coalescence, mechanism is a rapid process of condensation of cloud drops that subsequently collide and coalesce to form larger drops. The cold process results from the initial formation of ice crystals followed by a combined growth process from the vapour and riming. Temperature, humidity, aerosol content, cloud droplet size distribution and atmospheric and geographical conditions are the major factors that determine which precipitation-forming process will dominate. Irrespective of which process dominates, the clouds must attain a minimum vertical thickness to provide proper conditions for the time-dependent process of rain formation to become fully operative. The recognition of an opportunity for precipitation augmentation, on the one hand, and the decision to apply a given technique, on the other, depend on a comprehensive understanding of the nature of the clouds in question and of the degree of efficiency of the precipitation mechanisms to be applied.

Techniques

The rationale for the various techniques of seeding clouds to stimulate additional rain rests on the recognition that conditions may exist in the clouds in which a measured degree of artificial intervention can bring about known beneficial changes, and that ways and means are in existence for such artificial intervention. While these assertions are generally agreed upon, there are questions whether these specific conditions are properly defined and whether modification techniques have been applied in such a way as to produce the expected results. Nearly all the experiments conducted to date to augment precipitation involved the seeding of clouds with particles. The seeding was done to affect the clouds in one of the following ways:

(a) By enhancing the condensation-collision-coalescence (all-water) process;

(b) By initiating or increasing the growth of ice precipitation particles (cold process),

(c) By changing the dynamic properties of the clouds.

The first technique is very limited in its applicability because of the large material need and the severe requirements for the existence of suitable specific conditions. It can be effected either by water spray or by the use of hydroscopic materials. Both materials create a severe logistics problem due to the need for large quantities for a large-scale effect. Furthermore, this technique requires conditions in a cloud which themselves render natural precipitation mechanisms quite efficient.

The second technique involves adding the correct amount of seed agent (usually AgI) at the right time to suitable clouds. This can be expected to produce additional precipitation either by initiating precipitation in clouds that otherwise would not have precipitated due to a lack of ice crystals, or by increasing the precipitation efficiency in already precipitating clouds, mainly by the introduction of ice nuclei in warmer parts of the cloud where they would not naturally form. The magnitude of the effect depends mainly on the microstructure

and external dimensions of the clouds. It should be noted that if applied incorrectly this technique can decrease precipitation.

The third technique is rainfall augmentation by massive seeding aimed at affecting the dynamic properties of cumulus clouds. Cloud dynamics - the strength, size and duration of vertical air currents - have a major effect on cumulus precipitation. Generally, the larger the cloud the greater the chance that one of the mechanisms will progress to the stage at which the cloud precipitates. Techniques aimed at the "explosion" and merger of clouds have successfully augmentated precipitation.

Two questions arise, especially concerning the third technique, but in fact connected with the whole topic of rainfall augmentation.

Can multiple cloud dynamic seeding lead to rainfall increases over sizable areas without adverse side effects?

Can such effects be produced in a wider variety of climatic regions?

A partial answer to the first question is that rainfall is often redistributed, especially by the third technique, but that redistribution can be planned to be beneficial. The answer to the second question is that the suitability of any technique is dependent on the specific cloud type and surrounding atmospheric conditions. Further research may possibly define how to augment rainfall in a wider variety of circumstances.

A review of progress: assessment of results obtained in selected large-scale experiments

Most of the progress in augmentation has been based on large-scale, well designed experiments which either can provide physical and meteorological data which support the statistical analyses and show that observed effects can be related to a cause-and-effect relationship between seeding and precipitation, or are based on underlying physical concepts which are widely accepted but which require further testing to become fully instructive and of practical value.

These well designed experiments unfortunately constitute only a minority of the experiments undertaken. They include Project Whitetop, conducted in the central United States during 1960-1964; the Climax experiments in the Rocky Mountains of the United States during 1960-1965; the Australian cloud-seeding experiment during 1964-1967; the Florida single and multiple dynamic cloud-seeding experiments of 1965, 1968, 1970; and the Israeli rain stimulation experiments of 1961-1967 and 1969-1975.

It was found that, if properly executed, the seeding by AgI of cooler stratiform and cumulus clouds can increase rainfall. The actual increases varied between 10 and 25 per cent. Improper seeding, or over-seeding, however, can cause a decrease in rainfall. Seeding during either too cold or too warm conditions are among the reasons for negative results. The seeding can be

effected either by aircraft or by ground-based burners. It was found that both the condensation-collision-coalescence and the cold process cause precipitation; whichever dominates depends on a variety of local conditions. The major reason that some cooler clouds respond so well to seeding is that, although they have a high water content, they lack an ice crystal multiplication process, a deficiency which the addition of solid precipitation particles effectively overcomes. Seeding can be effective for quite a number of days a year. It can either cause precipitation in clouds which otherwise would not have precipitated or make the already existing precipitation process more efficient.

Dynamic cloud seeding can produce much more drastic effects; increases by factors of 3 and 10 were recorded. The effects can be achieved, however, under more limited conditions and also can reduce precipitation in areas where the clouds would normally precipitate.

Concluding remarks

Most cloud seeding experiments designed to stimulate rainfall are outside the category of experiments in a controlled environment. Their evaluation has relied on statistical techniques and has often been inconclusive. It is, therefore, still impossible to evaluate the costs and benefits of the precipitation produced. A critical question remains unanswered: is the added rainfall beneficial, i.e., does it add to the water yield and, therefore, the water potential?

It is possible to say that the progress made and the prospects of economic advantage justify intensified activities for furthering understanding of cloud physics and developing the methods of intervening in the rain-producing processes. There have been highly significant positive results under a variety of cloud conditions. They have laid a firm basis for the application of some of these experimental techniques within the framework of water-producing, cloud-seeding projects. One such carefully monitored operational programme is the use of the combination of ground-based and airborne generators to stimulate rainfall in the Lake Tiberias (Israel) catchment basin.

EVAPORATION REDUCTION

Introduction

Various methods and techniques for reducing evaporation have been considered since the beginning of this century. The spreading of oils in reservoirs to form a multimolecular layer for reducing evaporation was first reported in 1941. Extensive research on this subject, however, began only two or three decades ago.

In principle, the various evaporation reduction methods fall into two main groups:

(a) Formation of a monomolecular layer on the water surface which reduces evaporation by forming a physical barrier to the flow of vapour from the water surface to the air;

(b) Covering the water with insulating materials which reflect or filter some of the radiation reaching the water, thus forming an energy barrier which reduces the evaporation.

Use of monomolecular layers

For these methods to give good results, the monomolecular layer on the water surface must be maintained under various wind and wave conditions. Different means for spreading the monomolecular materials have been tried, including boats, aircraft and pipelines with portable or fixed sprayers along the shore. Irrespective of the spreading technique, the material used may be in crystal or powder form, in suspension in a suitable liquid, or in melted form. Spreading from the air is particularly suited to large areas where advantage may be taken of wind velocity.

Two recent series of large-scale experiments of this method of spreading layers were conducted in 1965/66 at Lake Hefner in Oklahoma and in 1969/70 at the Kishon reservoir in Israel. The experiment in Lake Hefner was conducted over an area of 10 km^2. The spraying was effected by fixed sprayers in the lake, not far from the shore. The experiment resulted in an average of only about 20 per cent coverage of the lake surface by the monomolecular layer. In the second experiment in the Kishon reservoir, the suspension was spread by floating sprayers which allowed a smaller discharge and a finer spray from each sprayer, resulting in an average of 80 per cent coverage of the target area (about 64 per cent of the entire lake).

Inverse relationships between area coverage and wind velocity and between wind velocity and the quantity of the material required per running metre were observed.

In the Kishon reservoir experiment a 22 per cent reduction in evaporation was observed at the beginning of the season. This was decreased and stabilized at about 10 per cent during the course of the season. This recorded decrease in the evaporation reduction has other causes which are coincidental and unrelated to the nature of the experiment. It is clear, however, that the accumulation of heat in the water reduces the real efficiency of the method significantly.

Cost estimates for each cubic metre saved by this method range from as low as $2.6 (reported in 1962) to as high as $25 (reported in 1967). The cost estimate for the Kishon experiment (1970) is at the higher end of this range. This cost estimate indicates that even with further technical improvements, this method will not become economically justifiable.

Use of radiation-reflecting materials

The use of radiation-reflecting materials has the advantage of reducing the net quantity of energy reaching the water body, although with insulated radiation-reflecting materials, a relative increase in water temperature was observed during the morning.

In the first experiments with floating microspheres, it was found that the materials used could promote evaporation because of their rotation and could, therefore, be drifted; winds and waves caused the particles to pile up. Recent experiments have shown that the resistance of the floating particles to dispersion depends upon their size and shape. In Italy it was found that increasing the diameter of the particles increased the rate of evaporation reduction; in Chile it was found that expanded polystyrene spheres reduced the evaporation by 40 per cent. It was also found that several types of floating plastic rafts could be very effective in controlling evaporation losses. Experiments with floating solid and granular materials (e.g., perlite ore) showed that these can provide practical means of reducing evaporation from open water surfaces. In one experiment a reduction of 35 per cent of the evaporation rate was achieved by covering about 50 per cent of the water surface with styrofoam panels.

The use of radiation-reflecting layers to reduce evaporation can interfere with the passage of oxygen into the water body. This has been observed in previous studies and additional research is required. Because of stability problems this method is not yet applicable to medium- and large-size reservoirs. Broad use of this technique will be possible only after a significant technical breakthrough makes it possible to spread particles in reservoirs to form a continuous cover which is stable under various wind and wave conditions.

Concluding remarks

At the current stage, none of the various methods for reducing evaporation has reached the point of practical application, except in some marginal cases. Additional technical research is needed to produce a technique which is feasible from an engineering point of view and at the same time economically justifiable.

CONCLUSION

This paper has surveyed some of the major advances in the development of non-conventional water resources. The development of most of these depends on techniques which are either not yet economically justifiable in most areas (desalination and sewage reclamation, for example) or not yet feasible in terms of engineering (cloud seeding and evaporation reduction, for example).

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Still, the increase in demand for water beyond the supply capacity of conventional water resources will, by necessity, impel the development of projects that will be feasible from an engineering point of view. At the same time, technological progress and breakthroughs will make certain developmental techniques economically justifiable. These techniques will, in turn, become conventional, and still other, more exotic sources of supply will then come to be termed "non-conventional water resources".

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INTERNATIONAL RIVER BASIN CO-OPERATION: THE LESSONS FROM EXPERIENCE

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Note: This report was prepared at the request of the Conference secretariat as a supporting document for the Conference. The views expressed are those of the authors and do not necessarily reflect the position of the United Nations.

PREFACE

The increasing importance being attached to international water resources development and management has prompted the preparation of this report, "International River Basin Co-operation: the Lessions from experience", as a supporting document for the United Nations Water Conference.

The report is based primarily upon case studies covering the experience with management and development of nine selected river basins throughout the world and one experience with regional co-operation. The case studies and the respective investigators who conducted the research are listed in the annex. Professor I. K. Fox, Director of the Westwater Research Centre, University of British Columbia, Canada, was responsible for the general co-ordination of the research effort and assisted in the preparation of the final condensed report.

INTRODUCTION

1. The world faces a critical shortage of water of suitable quantity and quality.

> "... globally there may be potentially enough water to meet forthcoming needs. But, frustratingly, it tends to be available in the wrong places, at the wrong time, or with the wrong quality. And in one way or another, all societies are affected, however rich, however poor" (E/CONF.70/CBP/1).

Political boundaries dividing a river basin or an aquifer aggravate the problem.

2. Water flows according to physical laws, irrespective of political boundaries. However, its use is governed by institutions and patterns of use responsive to political, social and economic demands. Where national boundaries divide a river basin, which is the physical unit for assessing and allocating water resources for various purposes, the co-riparians or co-basin countries must engage in a co-operative endeavour to rationalize use of the resource in terms of its capacity to meet the full range of the demands that exist.

3. The use of water by citizens of one country that shares a water resource may determine the benefits that the citizens of a co-riparian country can get from the same resource. Furthermore, use by one nation without regard for the potentials and demands in co-riparian nations can easily lead to inefficient use of available water supplies and inequitable sharing of the resources of a river basin. Such action can, in turn, result in ill feeling and political controversy of possible serious consequences.

4. International rivers, lakes and aquifers form a major part of the global stock of fresh water. There are over 200 continental river basins 1/ and many more tributary basins and aquifers that are divided by international boundaries. In view of the critical importance of using water resources efficiently to meet present and prospective demands for water in agriculture, industry and domestic use for the increasing world population, it is incumbent upon the nations of the world to find ways and means of achieving the best use of international water resources.

5. Improved management of international rivers, lakes and aquifers is not easy to accomplish. Some countries may have an economic incentive to ignore demands for basin-wide accords. Distrust and suspicion between States can reinforce one country's incentive to act alone or undermine endeavours that would be mutually

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1/ A continental river basin is one which is in direct communication with the final recipient of the water, i.e., ocean, closed internal sea or lake. The United Nations Department of Economic and Social Affairs has prepared a register of continental international river basins (E/C.7/21), currently under revision, which lists 214 such basins.

advantageous. Finally, some basin countries may not have the institutional and financial capability or the political interest to take advantage of opportunities for co-operative endeavours. These obstacles are difficult to overcome but progress can be made if there is, at least, the political will to co-operate.

6. Fortunately, in a number of regions of the world, nations have succeeded in working out fruitful arrangements for managing and using international water resources. Some of these experiences have been summarized and assessed in 10 case studies prepared for the United Nations Secretariat which provide a basis for arriving at some conclusions about how to foster constructive action, to manage and utilize international water resources efficiently and fairly. This statement is based on those reports. First, it seeks to define the nature of the problems that must be dealt with in the management of international water resources. Secondly, by drawing upon the experiences reported in the papers listed in the annex, it seeks to illustrate how co-operative action has been achieved and the kinds of institutions that have facilitated co-operative action; a concluding section summarizes the kinds of measures and institutional arrangements that experience suggests will foster the best use of international water resources.

I. THE PROBLEM: FACTORS INFLUENCING THE CAPABILITY TO UNDERTAKE CO-OPERATIVE ACTION

7. The factors that influence the capability of co-riparian nations to engage in co-operative action to manage an international water resource may be classified into six categories, as follows:

(a) The differences and similarities in the evaluative frameworks of co-riparian nations;

(b) The uncertainties that exist with regard to the possible future effects of any joint arrangement;

(c) The physical-economic characteristics of the water resource management system as related to international boundaries;

(d) The international relations environment;

(e) Domestic factors within the co-riparian nations;

(f) The number of nations involved in the negotiation.

Each of these merits brief elaboration.

The evaluative frameworks of the co-riparian nations

8. It is a premise of this statement and it is generally accepted that important objectives in the management of an international water resource are to maximize net benefits from the resource and to achieve an equitable sharing of the benefits

realized. It is widely recognized that in the consideration of benefits and costs are included much more than measurable economic effects. Benefits might include, for example, beneficial social and ecological effects, and costs might include uncertainties with regard to the likely consequences of a given course of action. In some cases, the political effects of water development may be regarded as a benefit or a cost. Each nation seeks to take into account all the benefits and all the costs associated with the development of an international water resource, but experience has demonstrated that it is extremely difficult to reach agreement among co-riparians on how to weigh such benefits and costs. Since nations have differing priorities which come, in part, from differing political, social and economic conditions in each country and, in part, from differing cultural heritages, it is generally not practicable to arrive at an objective statement of benefits and costs that is both comprehensive and acceptable to the co-riparian nations. As indicated in the case studies which follow, practical means of surmounting this obstacle have been found in a number of situations.

Uncertainties with regard to possible future effects

9. It is, of course, difficult to foresee the long-term consequences of an international agreement in the management and use of international water resources. Since certain types of water development actions, such as the building of a dam, are virtually irreversible and since an international agreement limits the ability of any one nation to change the course of action agreed upon, the uncertain consequences of an agreement constitute an important obstacle to joint action, an obstacle that cannot be completely overcome by investigation and analysis.

The physical-economic characteristics of the water resource management system

10. The potential uses for which a river can be managed and the location of developmental and use activities in relation to the location of political boundaries influence in a significant way what the incidence of benefits and costs will tend to be, and determine the kinds of arrangements that will be necessary to achieve what will be mutually regarded as an acceptable sharing of such benefits and costs. Some patterns that result from the physical-economic characteristics of a water resources system are more amenable to co-operative action than others. These various patterns may be classified into three types which pose differing kinds of incentives and disincentives for nations to co-operate.

Potential benefits to one riparian State undiminished by the same type of use by co-riparians

11. This type of situation applies primarily to navigation uses, although in theory it could apply to others. If an international river has potential for navigation use, each co-riparian can engage in such use without impairing the

benefits from similar use by other co-riparians. In such cases, the international agreement need involve no more than a guarantee of freedom of navigation such as has been in operation in the Rhine since the Treaty of Vienna in 1815. If improvements are necessary to facilitate navigation, agreement will be necessary on the sharing of the costs of such developments. Since in this type of situation each riparian country can benefit from an agreement at little cost to itself or little damage to the resource, navigation agreements tend to be the easiest to negotiate and therefore, historically, they have been the earliest form of international water resource co-operation.

Each riparian State has equal access to use of the resource but use by one diminishes potential benefits available to co-riparians

12. Water resources within a region are normally of a fixed stock. Thus, where countries share a water resource which forms an international boundary between them, i.e., a contiguous river, lake or aquifer, use of the resource either for abstraction or waste disposal will decrease the potential benefits for similar use by the neighbouring States. Extreme competition over a fixed common resource leads to the "tragedy of the commons". In this case, the benefits from use of the resource are captured by the country using it while the costs in terms of degradation and depletion of the resource are shared with the neighbouring countries. This can lead to a competitive situation in which each country seeks to capture as much of the benefit from the resource as possible before it is no longer usable. Fortunately, in the case of inland water resources the number of States along an adjacent water resource is usually small enough so that the cost of the destruction of the resource, although shared, is sufficiently high for each to have an incentive to seek a common solution for its management; hence, benefits from use of the resource can continue. As indicated in the case studies below, this type of problem is being dealt with effectively in numerous regions of the world, the Great Lakes region between the United States of America and Canada being a prominent example.

Potentials exist for increasing benefits to all co-riparians through integrated development of a river basin

13. There are opportunities for increasing the total net benefits from the water resources of a region beyond the benefits which can be realized through independent action by each co-riparian, by undertaking a co-ordinated programme of development for the entire international river basin. For example, regulation of the Senegal River will provide flood control and hydropower production and permit development of navigation works in the three participating basin countries - Mali, Mauritania and Senegal. In this case, it is necessary to conceive of a programme which will maximize net benefits without regard to international boundaries and then seek agreement on a sharing of the benefits and costs that all co-riparians will regard as equitable. While the potential increase in benefits derived from integrated development results in a powerful incentive to reach agreement on an integrated programme of development, differences in evaluative frameworks (referred to above) and different views on how the costs and benefits

should be divided pose difficult problems to be overcome, which have resulted in many years of negotiation before agreement would be reached in a number of regions. For example, planning and negotiation for integrated flood control and hydropower production in the Columbia River between Canada and the United States took 20 years.

14. This type of problem is generally found in river basins where countries lie in an upstream/downstream relationship to one another, i.e., in successive international rivers. Two situations can be identified in this case:

(a) An upstream country may abstract water or impair water quality and thus reduce the benefit available to downstream countries while the downstream countries are unable to impose similar costs upon the upstream country. Thus, the upstream country has no economic incentive to reach an agreement, and reliance must be placed upon other types of incentives if mutually acceptable joint actions are to be achieved;

(b) A downstream country located at the mouth of a river flowing to the ocean might, without constraint, not only withdraw water from the river but also pollute it. Thus, this downstream country may enjoy a competitive economic advantage over upstream countries which may have to abide by pollution control regulations or agreements among riparian countries.

15. Both the above situations exist, for example, on the Rhine River where, fortunately, a number of incentives have been found to foster co-operation among the co-basin countries.

The international relations environment

16. Considerations entirely divorced from the economic incentives for use of an international river affect the willingness of basin States to work together. The foreign policy orientation of a country, the history of relations among riparian countries, differing interpretations of and commitments to international legal principles, nationalism and sovereignty considerations are some of the types of issues that can either make for an atmosphere conducive to co-operation or may, at the extreme, poison it. Where the foreign policy stance is positive towards neighbouring countries, even the disincentives for co-operation in an upstream/downstream situation can be overcome. This was the case, for instance, of the Colorado salinity issue in which the United States agreed to reduce the salt concentration of the water it passes on to Mexico, and the earlier 1944 Colorado River Treaty apportioning the river's waters between the United States and Mexico. On the other hand, where there is ample economic incentive, management and development opportunities can be undermined by incompatible foreign policy objectives or a long history of suspicion and mistrust.

Domestic factors

17. Factors internal to each of the riparian nations as well as the international relations environment influence the prospects for joint action to manage a water

resources system. These include the nature of the governmental system, institutional mechanisms for national policy formulation, the strength and role of interest groups, the nations' priorities for resource development, and the technical and financial resources available for co-operation in water resource development.

18. These factors warrant little elaboration in this statement. It is evident that where authority is divided between national and regional governments, as in the federal systems of Canada and the Federal Republic of Germany, an extra dimension is added to the negotiating process. Some countries have more highly developed policy mechanisms than others. Interest groups are very active in national policy formulation in some countries and, thus, play a major part in establishing national policy with regard to a possible agreement on the management of an international river. The reaching of an agreement may be of high priority in one country and of relatively low priority in another. While such factors may have an important bearing upon the capability of the riparian nations to reach agreement, little can be done to deal with any obstacles they create except upon the initiative of the individual country. On the other hand, if the technical and financial resources available to one or more of the countries limits effective co-operation, the international community can be of assistance. In section II below there are notable cases where such assistance has been provided.

The number of nations involved in the negotiation

19. The problem of achieving agreement in joint action increases with the number of nations involved. It is self-evident that it is generally much easier to reconcile differences between two countries than among three, and as the number increases, the problem of achieving agreement becomes progressively more difficult.

II. LESSONS FROM EXPERIENCE: WAYS OF FOSTERING CO-OPERATIVE ACTION

20. As the foregoing presentation suggests, the problem of achieving co-operative action will vary greatly from situation to situation. If the nations involved have a common cultural heritage and a history of good working relationships with one another, the task of achieving agreement is much simpler than it is if these conditions do not exist. The strong foreign policy differences between countries in the Senegal basin which might have threatened integrated development of the basin was, in part, eased by bonds in terms of a common working language, similar judicial arrangements and similar bodies of law and government organization. In the Volta basin, a long history of bilateral and multilateral relations between Ghana and its riparian neighbours made natural early discussion of joint development opportunities. Certainly, in the case of the Columbia River Treaty between the United States and Canada the common cultural background and language and a long history of friendly relations between the two countries facilitated the negotiation of an agreement. The physical-economic characteristics of the water resources management system as related to international boundaries can make

the task a particularly easy one. For example, if a waterway can be used by one State without depriving another State of potential benefits, little difficulty in reaching a navigation agreement should be encountered.

21. Our concern, of course, should be with the more difficult situations where agreement does not come easily. In these cases, we must seek to understand the kinds of steps that can be taken to facilitate joint action and that will foster best use of water resources and equitable sharing of the benefits. At the same time, it must be recognized that a number of factors that tend to slow up the agreement process, such as the domestic factors described, are not susceptible of modification or change, except in a context that extends well beyond the management of international rivers. Needless to say, in the more difficult international water resources situations there is no substitute for a conscientious endeavour - a will to co-operate - on the part of each nation involved. Beyond this critical element, experience indicates that there are a number of concrete things that can be done.

22. In considering the kinds of things that can be done, it is essential to keep in mind that each riparian State must determine what pattern of development and use most nearly accords with its concept of what constitutes efficient use of the resource, and a fair division of the benefits and costs. Efforts to facilitate agreement must aim primarily at providing a deeper understanding of what the realistic options are and what the effects of each option, if implemented, are likely to be.

23. There follows a listing of the kinds of things that might be done, as suggested by experience in the river basin situations listed in the annex.

Careful attention should be given to generating information about the effects upon each riparian country involved of alternative schemes of development and use

24. The World Bank recognizes from its experience assisting in international river projects that, in addition to goodwill, the commitment of basin countries to reach agreement, and their willingness to share technical and economic information is an essential condition for success. A sufficient array of technical, economic, legal and other pertinent data is required so that each Government and any external financing or other agency involved can be satisfied that the solution proposed is equitable and feasible. This will require as a necessary condition full information on the net benefits to each country from each alternative.

25. In case after case, agreement could only be achieved after the basin countries were equipped with sufficient information and capable of assessing by themselves the consequences of alternative courses of action, to permit national leaders to negotiate with confidence that the proposed endeavours are really the best available to a country and could be equitably sustained over time. For the Indus Treaty, the massive array of information collected and the preparation of engineering studies of numerous alternative development plans permitted each

Government to evaluate the relative equity of any proposal. In the same way, the accumulation of information from a number of planning and project studies proving the value of integrated development of the Senegal River provided a basis for successful negotiation for joint development.

26. The planning arrangements for the Pilcomayo River in the Río Plata basin deserve a brief review since they are indicative of the careful preliminary thought that should be given to the type of information to produce and the manner in which the information should be used. In this case, the investigations were designed to fill in gaps in basic data and knowledge needed for further planning, provide recommendations flexible enough to adjust to the anticipated long-term period for implementation, and tailor, as closely as possible, the information produced to the needs of the basin countries.

27. A two-phase study has been initiated. The first phase seeks to remedy deficiencies in basic data and information regarding the area's natural resources, social, productive and infrastructural conditions. The study will go on to establish development possibilities including the financial implications and feasibility for the basin countries. Information from this phase will provide the basis for political decisions on the priorities for development in the various sectors and the degree of development intended to be achieved in the basin. The second phase will follow up the first by investigation of specific components of the first study and selection of an alternative plan that is compatible with the regional and national objectives.

28. An important feature of the investigations is the composition and role of the co-ordinating committee which is composed of representatives from the basin countries and the three aid organizations - the United Nations Development Programme (UNDP), the Organization of American States (OAS) and the International Development Bank (IDB). It will direct studies so that the proper information is produced and then utilized by the basin country's political leaders. Through periodic revision of the investigation, it can inject the concerns, objectives and recent thinking of the leaders in the basin countries to ensure that once the studies are complete the findings will be relevant to them. It is hoped these pre-feasibility studies will produce the information that indicates the advantages of going on to the next phase which will require detailed feasibility studies, procuring investment funds, and the design of international and national organizational structures for the implementation and management of the recommended projects.

29. Information generation can be costly. The Vardar-Axios investigations have cost about $5 million. However, since well-founded information is the key to ensuring that co-operative arrangements are relevant to national needs, investment in this sector is a critical initial condition to foster co-operation.

Possibilities entirely within each country for providing the services from water resources that might be secured through international action should be fully explored

30. Togo and Benin, before commiting themselves to the purchase of much needed

power from the Akosombo Dam in Ghana on the Volta River, explored the prospects of developing their own hydropower resources in the Mono basin. The results from these United Nations-assisted studies were encouraging. The studies showed that a firm basis for co-operation could be worked out. The Mono project would take 10 years to construct and in the interim period it would be profitable for the two countries to arrange for the purchase of Ghana's Volta power. On the Black Volta River between Ghana and the Upper Volta both countries recognized joint development opportunities for power development, but both sides are proceeding with feasibility studies of sites located entirely with their own countries (the Noumbiel site in the Upper Volta, the Bui site in Ghana). As well, Ghana is investigating a site along a common reach of the river. The studies, conducted separately although co-ordinated, will provide information on domestic alternatives to meet current needs which should make clear whether there is a present or future area of mutual interest which each side can satisfy through joint development.

31. The recognition of the relative merits of domestic alternatives to international ones is an important first step in assessing each country's interest in joint development of a shared river. Domestic projects, if they can accomplish many of the same objectives as international ones, are likely to have more appeal, for they receive nationalist support, add to national prestige, have greater national and regional impact since the benefits of the project are not shared, and they avoid entangling international arrangements that may restrict a country's flexibility in making policy. Only when each country is satisfied that the international alternative is the best option open to it is there a firm basis for co-operation.

32. The Senegal River is a case in which there is not only a common interest among the three lower riparian countries but, in addition, the interest is complementary. Development of the river, principally through a major dam at Manantali in Mali to regularize the downstream flow, will help to ease common constraints such as poor transportation infrastructure, vulnerability to drought and high energy costs, as well as meet the pressing needs in each country - agricultural and livestock development in Mauritania which is totally dependent on the Senegal River, diversification of the ground-nut crop in Senegal upon which that country solely relies, and access to the sea and the reduction of the high cost of energy for Mali. The recognition of this mutual dependence has been perhaps the major reason for the progress now being made in the development of the Manantali Dam and other works in the basin.

> If a nation is limited in its ability to undertake adequate technical, economic and social studies, international agencies and members of the international community should provide needed assistance and also aid in the training of professional personnel within the countries involved

33. In order to generate information about alternative schemes of development, in order to assess the advantages of co-operation and in order to proceed with

the construction of projects, expertise is required in a number of subjects. If, for lack of experience and trained personnel, this expertise is not available for one or more of the co-basin countries, outside assistance must be sought. Actually, assistance may be valuable even if basin countries already have a relatively high degree of professional competence in the water resource field, such as Greece and Yugoslavia had in the Vardar-Axios basin project. In this case, systems analysis techniques developed elsewhere were brought in to strengthen the capability of each country to assess the integrated development potential of the basin.

34. If such involvement by outside experts and the adaptation of foreign technology and know-how are carried out properly, it should have the additional benefit of training local personnel and lead to a higher level of national self-sufficiency in the field. In the Pilcomayo River development programme which has been assisted by OAS, UNDP and IDB, training of personnel from the three basin countries is a specific objective of the study.

35. In some situations, it might be appropriate to create regional training institutes on a permanent basis. These would certainly be concerned not only with international rivers but also with other relevant aspects of national river basin development. The advantage of such institutes derives from the need to pull together scarce resources and they should also help to build confidence and mutual respect among professionals of the co-basin countries.

A concerted effort should be made to secure basic agreement on the technical aspects of alternative management and use schemes

36. Negotiations on substantive normative issues will be needlessly complicated and prolonged if there are disagreements over basic technical issues. These technical matters can readily be resolved by working groups of experts from the basin countries or a more structured joint technical committee in charge of co-ordinating and integrating basic data-gathering and technical feasibility studies. Negotiations for the Columbia River Treaty between Canada and the United States was aided by agreement on the possible alternative schemes and on the supporting hydrologic and engineering data. In this case, each side acquired confidence that the information was correct and impartial because it was generated by a joint advisory engineering board under the respected and unbiased International Joint Commission (United States and Canada). Agreement on the technical basis for co-operation freed the negotiators to concentrate on the important issues of alternative selection and the division of benefits and costs for the selected projects.

Continuing communication and exchange of information at the technical as well as at the political level should be encouraged as a means of building mutual trust among the co-riparian nations

37. Continuing communication at the technical level has been an important factor in encouraging basin-wide co-operation. Co-operation is built upon trust and

understanding. This can be most readily achieved by building upon positive experiences. Technical exchanges in which there is a minimum of political judgement make for positive working relationships between personnel from the basin countries. Integration of an agreed-upon limited range of technical functions through both informal and formal international institutional arrangements can, in addition to providing mutually accepted information which is the basis for fruitful negotiation, develop the confidence and trust between basin country personnel needed for further joint undertakings.

38. For example, continuing contacts through technical sessions and discussions between technical personnel from the Volta River Authority in Ghana and the Communauté d'électricité du Bénin (Benin and Togo) have spread mutual trust, understanding and the desire to achieve acceptable solutions which have opened the way for closer future co-operation for the Volta system. For the Vardar-Axios River, regular biannual meetings of the Joint Yugoslav-Greek Commission for the Vardar-Axios and monthly meetings of its Co-ordinating Directorate provide a focus, sense of urgency and incentive for teamwork, as well as mutual understanding of the differing socio-economic approaches to technical reports, contractual procedures and criteria of judgement. Functional responsibility of the Directorate to authorize payment for local contracting works helps provide an ongoing aim and purpose to the international meetings. For the Commission, continuity of membership has enabled the commissioners to get to know one another and develop an atmosphere of greater mutual confidence which is expected to be helpful in reviewing the final reports and technical conclusions.

39. The effort to promote communication and understanding will require time, effort and funds. For example, the Vardar-Axios studies for integrated development were delayed because of the unanticipated time required to translate reports and documents from the local language to the common project language and vice versa. In spite of the delay, the translation of documents was essential to establish communication by ensuring full comprehension of the contents of all reports and documents by all concerned.

Imaginative ways of sharing benefits and costs so as to provide the necessary incentives for agreement should be fully explored

40. The basic incentive for co-operation is that each nation must gain some net benefit. Sacrifices in achievement of a joint objective must be more than compensated for by an expected benefit. A wide range of incentives may be encountered. Most common are direct economic benefits from projects located on national territory, such as the substantial increase in the Nile flow obtained through projects to prevent loss of water in the swamps of the White Nile in the Sudan, which are equally financed by the Sudan and Egypt and which benefit not only Egypt but the Sudan as well; or the indirect cash compensation received by Canada as its reward for constructing storage dams on the Columbia River within its territory for hydropower production and flood control downstream in the United States; or the direct cash compensation received by Pakistan from India to compensate for loss of the water from the Indus tributaries that normally flowed to Pakistan.

41. However, in some cases, especially in sequential river situations where the upstream country can realize little advantage from co-operation, a more flexible approach to encourage joint actions may be appropriate. Benefits such as improved trade links may be used as an inducement by one country to get another to co-operate. Where upstream countries are degrading the river for use by the downstream countries, the downstream countries - contrary to prevailing opinion regarding the "polluter pays" principle - may have to pay for the cost of stopping the damaging activity. For example, recently the three Rhine countries - the Netherlands, Federal Republic of Germany, and Switzerland - agreed to help pay France part of the cost of storing the salt discharges from the potash mines in Alsace that France normally discharges into the river. The downstream country may also draw to the attention of the upstream country values it holds in terms of international law, neighbourly relations, or some other foreign policy consideration, such as those which influenced the United States to reduce the salt concentrations of the Colorado River water it passes on to Mexico. These examples indicate that a flexible approach should be taken to ensure that all the basin countries will have some incentive for agreement and there is a basis for agreement.

The international community should continue to build a consensus as to what constitutes an equitable division of the benefits and costs resulting from the development and use of international water resources

42. Resolutions 21 and 22 on States' responsibility and liability, adopted at the United Nations Conference on the Human Environment; the Helsinki Rules; the proposed European Convention of the Protection of International Watercourses against Pollution and the Principles on Trans-frontier Pollution of the Organisation for Economic Co-operation and Development (OECD) are all global and regional principles and rules of conduct which, if adhered to by basin States, can facilitate co-operation. They help reduce the issues to be settled in negotiation by pointing out the responsibilities expected of each country and setting out principles for the equitable division of the benefits and costs resulting from the development and use of international water resources. International river issues often entail conflict between public international morality, as expressed by international law, and basin State self-interest. There are few sanctions to apply against those countries which disregard internationally accepted rules of behaviour and accepted principles of sharing, except the disapproval of the international community. Thus, to counter the strong self-interest incentives open to a basin country in a favourable location within the basin, efforts should be made by the international community to elaborate appropriate principles of equitable use of international rivers, but the principles worked out must be the result of intensive consultation between Governments to ensure that they represent something close to a consensus. The international legal community has made much progress in building such consensus on the general principles of the equitable utilization of international rivers but much more work needs to be done to strengthen the consensus and expand the principles, thus making them more comprehensive in application to the many different types of international river situations.

If a nation does not have the financial resources to undertake its share of a potential joint development programme, international lending institutions and members of the international community can make important contributions in the provision of funds

43. In many basins, the opportunities for development cannot be realized unless the basin countries receive outside assistance. Multilateral and bilateral financial assistance between organizations in the donor countries and particular basin countries can help bolster the capability of a basin country to take advantage of its opportunities on a shared river. However, it is important that this type of bilateral and multilateral assistance be extended to all basin countries needing assistance and that this assistance be co-ordinated and complementary.

44. In 1956, Pakistan and India with assistance from the World Bank were discussing a sharing arrangement for the waters of the Indus system. The waters of the river and its tributaries would be divided and those that formerly flowed into Pakistan from India would be replaced, in part, by storage works on the western rivers in Pakistan through connecting canals. However, agreement was not reached at this point because, as the Bank admits, it was slow to appreciate that neither country could meet the cost of those works necessary to effect replacement. Solution to the controversy could not be reached until funds could be found to finance these works from sources outside the basin countries. The World Bank helped establish the Indus Basin Development Fund to which outside countries such as Australia, Canada, the Federal Republic of Germany, New Zealand, the United Kingdom and the United States contributed. The Indus case points out the importance of the planning and negotiation stage to account for the financial capability of the basin countries to undertake the works needed, to ensure an equitable agreement and the important role international lending institutions play in strengthening the financial capability of the basin countries. Where the financial capability is lacking, attention must be given to finding outside sources at the time a feasible alternative is decided.

45. An example of a successful bilateral aid approach was a simultaneous request by Ghana, Togo and Benin to the Canadian Government to finance first a study and finally the cost of transmission facilities linking the three West African countries, to permit the sale of the surplus power of the Akosombo Dam in Ghana to Togo and Benin. On the other hand, in another part of the Volta system a recent mission of the United Nations Conference on Trade and Development (UNCTAD) pointed out that bilateral assistance from France and Australia could have been better integrated. Funding by France of feasibility studies and site investigations of the Noumbiel site in the Upper Volta on the Black Volta River and the Australian aid for similar studies on the Bui site in the Ghanian reach of the river could have been more closely integrated by the creation of a control agency to co-ordinate the work of the consultants.

In order to minimize the potential for friction among nations involved over basin implementation arrangements, agreement should limit as much as is possible the dependence of one nation upon continuing actions by another to realize its share of the benefits

46. Countries are often reluctant to enter into joint arrangements if projects that will be vital to their economy and development are controlled by another basin country. There can be no guideline stipulating the degree of sovereignty control over projects, for the requirements for each situation are unique. However, to reduce the unease over potential loss of sovereignty entailed in international co-operative arrangements, strategic works should, as much as is practical, be designed and located in such a way that each State retains as much control as possible over works on which it is greatly dependent. One need only note that a key point to the solution of the Indus River controversy between Pakistan and India was to find a scheme in which Pakistan would have control over the works upon which it would be most dependent. Also, the awkward position Zambia faced by not having any sovereign control of the powerhouse for the Kariba Dam it shares with Southern Rhodesia on the Zambesi River when that country illegally declared independence is indicative of the situations countries fear might occur if they do not have the necessary control to assure protection in case of drastically altered political relations between countries.

International agreements should be as flexible as practicable in order to permit adjustments in water use and management in response to unforeseen changes in conditions

47. Inflexibility of an agreement will freeze the political motivations, technological possibilities and economic conditions at the time of signing. Some inflexibility is unavoidable; dams, once constructed, are a permanent commitment to one form of technology and have only limited possibilities for modification in response to new technologies. Nevertheless, given this limitation, flexible co-operation is possible. A treaty should constitute a framework which sets out the principles upon which joint development can proceed, with detailed planning and implementation of projects left to joint technical groups operating under political direction. This permits a response to changing economic and technological circumstances within the terms of the agreement, without the need for renegotiation of a major international undertaking. In the Columbia River development, there is strong evidence that if Canada and the United States had not tied themselves so firmly into one pattern of development in the Treaty in the period after the Treaty was signed and before the projects were implemented, they could have taken advantage of changing technical conditions and other circumstances and modified their original plans to produce greater benefits than those under the Treaty.

48. In addition to flexibility in project design and implementation, treaties and agreements between basin countries which call for development based on shared costs and benefits should be flexible enough to maintain an equitable division of

Pollution. Many issues, such as hydropower generation or navigation improvements, are worked out on a bilateral basis between Switzerland and the Federal Republic of Germany. Further, increasing progress is being made in co-operation at the subnational level between regional authorities in neighbouring countries for local issues. The Moselle and the Saar tributary basins are dealt with separately again by the tributary basin countries - France, the Federal Republic of Germany and Luxembourg for the Moselle; France and the Federal Republic of Germany for the Saar. These subbasin arrangements have simplified negotiations by reducing the number of participants to those countries which have the most interest in the issues at stake.

Where an international river is expected to reach a high degree of development and use, the basin countries should give early consideration to joint planning in order to avoid conflicting claims on the resource that may arise in the future

52. Disputes arise when demands on a common resource exceed the resource's capacity to meet them. In many cases, these types of disputes can be avoided by the basin countries if they compare the projected demands by each country on the river water. This will reveal the incompatibility of claims. Given time, joint plans can be drawn up to regulate the flow to increase the capacity for use, to apportion the waters, or to work out some other scheme to use equitably the shared resource without conflict.

53. Greece and Yugoslavia exchanged information for the Vardar-Axios and found that the plans for development of the resource were greater than the supply available. The incentive for co-operation became to avoid conflict over possible future water shortages. Integrated development of the river before the shortages occur will increase storage capacity and regulate the flow to meet the needs of both countries. Similarly, the impetus for the creation of the Niger Commission in the early 1960s came from the realization that projects being independently considered by Guinea, Mali and Nigeria would have adverse effects on major downstream projects by the 1990s.

III. LESSONS FROM EXPERIENCE: INSTITUTIONAL ARRANGEMENTS TO FACILITATE JOINT ACTION ON THE MANAGEMENT AND DEVELOPMENT OF INTERNATIONAL WATER RESOURCES

54. Organizations concerned with the development and management of international water resources can be divided into three categories, namely: river basin agencies; national water resources organizations; and global and regional organizations. Experience has demonstrated that each of these categories of organizations can contribute in important ways to co-operative action with regard to the management and use of international rivers.

River basin organizations

55. Special international organizations have been established in many parts of the world to facilitate the management of international lakes and rivers. They perform many functions with varying degree of authority and effectiveness in promoting co-operative action. The International Commission for the Protection of the Rhine against Pollution has data-compiling duties and investigatory functions through its working group, but is limited in making recommendations by a unanimity rule. In contrast, the Central Commission for the Navigation of the Rhine has extensive approval authority over the construction of works on the river which may affect navigation and regulatory authority over the vessels which use the river. L'Organisation pour la mise en valeur du fleuve Sénégal (OMVS) has achieved impressive results and has authority over the development and management of the dams regulating the flow of river and port development and operation from the delta to Kayes in Mali. The Niger Commission, on the other hand, provides only a framework for negotiation between the nine basin States with few planning functions. The joint Yugoslav-Greek Commission for the Vardar-Axios River reviews the technical and planning studies of the Yugoslav, Greek and United Nations investigative team while the Co-ordinating Directorate for the investigation is responsible for the co-ordination of all activities. Ghana participates in both formal and informal arrangements with its neighbours. Through formal organizations such as the Ghana-Upper Volta Permanent Joint Commission for Co-operation and the Transport, Communications and Works Committee, planning for development of the Black Volta is co-ordinated. On an ad hoc basis the Volta River Authority (VRA) arranges for the distribution of surplus electricity from the Akosombo Dam in Ghana on the Volta with the Energie électrique de la Côte d'Ivoire (EECI), and with Togo and Benin, latterly through the Communaute d'électricité du Bénin (CEB). With a broader mandate the International Joint Commission (IJC) between Canada and the United States approves works on international rivers that affect water levels and water quality at the international boundary, carries out joint investigations and conducts public hearings at the request of the Governments and establishes technical boards such as the International Columbia River Engineering Board to plan integrated development or to handle special technical water management issues. The International Boundary and Water Commission between Mexico and the United States is responsible for works along the water boundary between the two countries.

56. Several conclusions emerge from the experience with river basin organizations in different parts of the world. These may be briefly summarized as follows.

(a) Communication among national representatives through meetings of river basin organizations can help build mutual trust and confidence among co-riparians.

(b) Development of an elaborate formal organization and procedure is not an important prerequisite for success.

It is important instead to design the organization in accord with prevailing political and economic realities found in the particular basin of concern. It is noteworthy that Ghana and its neighbours have through informal means developed good working relationships. Starting with

contacts between heads of departments and some fairly autonomous agencies such as the Volta River Authority of Ghana, technical findings, data and other information were exchanged which led to discussions of issues of common interest among technical personnel. Those discussions in turn helped in building up the mutual trust and understanding needed for negotiation and agreement on a political level.

(c) It is important that the river basin organization have a limited mandate and focus sharply upon issues of mutual interest.

The success of the informal negotiations of Ghana and its neighbours referred to above is attributed in large part to limiting discussion carefully to areas of mutual interest. The negligible accomplishments of the Organisation des Etas riverains du fleuve Sénégal (OERS) in comparison to the present OMVS resulted from too broad a mandate. The OERS sought, in conjunction with river basin development, extensive cultural, social and scientific co-operation. In comparison, the present OMVS more directly focuses its work on river basin development in which there are clear reciprocal benefits. Its success in comparison to its predecessor indicates the importance of designing institutional arrangements based on areas of common interest which are not so easily paralyzed by outstanding bilateral political issues.

(d) River basin organizations have been most effective when they have concentrated upon reaching agreement on the technical aspects of alternative schemes and have avoided efforts to resolve political issues.

This conclusion has two aspects. On the one hand, limiting an organization's responsibility to data collection and exchange does not realize the full potential of a commission. On the other hand, assigning responsibility to such an organization for the resolution of political issues will tend to limit the capability of the organization to deal effectively with important technical matters which must be dealt with to provide a basis for effective political action. Experience suggests that negotiations on political issues should be handled by national political representatives who specialize in such activities. This conclusion is well supported by the procedure followed in the case of the Columbia River Treaty. The International Joint Commission (United States and Canada) investigated and analysed the technical consequences of alternative development schemes. These analyses provided the basis for the political negotiations which were undertaken by a separate group.

National organizations

57. Effective river basin management and development is dependent on the full commitment of the basin Governments. Water resource agencies and departments have the responsibility to create the conditions that enable the national political leaders to appreciate fully the opportunities and responsibilities for and constraints from joint use of development of an international river. If an international river basin organization exists, the relevant national organizations will undoubtedly be called upon to participate in its work.

58. The importance of the national organization to the success of co-operative efforts to manage international water resources cannot be over-stressed. As noted in the case studies in section II above, the willingness of a nation to co-operate in a joint endeavour will depend upon an assurance that it understands the consequences of alternative courses of action. For such understanding it must rely in the final analysis upon its own water resources agencies. Furthermore, it must have well equipped water resources agencies to participate in the implementation of programmes agreed upon.

59. Unfortunately many nations still do not have agencies with well trained staffs of sufficient size to discharge these responsibilities effectively. Thus a major objective of technical assistance by the international community must be to strengthen national agencies where the need exists, so that each nation can participate effectively in the investigation and analysis of alternative development and management schemes for international water resources systems.

Global and regional organizations

60. This category includes the United Nations, its sister organizations and regional bodies such as the Organization of American States and the Council of Europe. These organizations have made three principal kinds of contributions: generation and dissemination of technical and legal information and provision of technical assistance, financing and training.

61. A report of the Secretary-General on international river basin development 2/ to the United Nations Committee on Natural Resources at its fourth session gives an overview of the activities in the field of the United Nations and related bodies, as well as several other global and regional organizations. Here it will suffice to give a few examples of the contributions made by various international organizations in each area of activity.

Generation and dissemination of legal and technical information

62. The efforts of the United Nations system in the area have varied from the convening of panels of experts and seminars to the publication of various documents dealing with the technical, economic, legal and institutional aspects of international water resources development. Since the first symposium on Comprehensive River Basins Development was convened by the United Nations at Lake Success, New York, in 1949, the Secretariat has carried out an extensive programme of meetings and publications related or specifically oriented to international water resources.

2/ "Water resources development: international river basin development: progress report of the Secretary-General on related activities" (E/C.7/46).

Two publications are especially worthy of mention: Integrated River Basin Development and Management of International Water Resources - Institutional and Legal Aspects. 3/ The United Nations Institute for Training and Research (UNITAR) and the Organization of American States have also contributed towards disseminating information in the general field of international rivers through various published reports. 4/

63. These types of publications are important because they provide useful guidelines on the technical and institutional issues on which attention should be concentrated, particularly in cases where the development of an international river basin is in the initial stages.

64. The United Nations system has also produced a number of documents dealing specifically with the legal aspects of management of shared water resources. The Secretariat has published a series of reference materials 5/ and the Food and Agriculture Organization of the United Nations (FAO) and the International Law Commission have reviewed bilateral and multilateral treaties and conventions relating to the uses of international water courses and published reports on the subject. 6/ These works provide one important type of input to further the development of legal principles for international river basin use. In this regard, mention should be made of the work currently being carried out by the United Nations Environment Programme (UNEP) on co-operation in the field of the environment concerning natural resources shared by two or more States, which promises to clarify many important questions concerning principles of conduct of States in international water resources development and management. 7/

3/ United Nations publications, Sales Nos. E.70.II.A.4 and E.75.II.A.2

4/ See, for instance, International Navigable Waterways (United Nations publication, Sales No. E.75.XV.ST/6) and "Textos de documentos sobre el uso commercial de rios y lagos internacionales" (OEA/SER.I/VI.1.CIJ-97).

5/ Among the most important are "Legal problems relating to the utilization and use of international rivers" (A/5409), vols. I, II, III and Legislative Texts and Treaty Provisions concerning the Utilization of International Rivers for Other Purposes than Navigation (United Nations publication, Sales No. 63.V.4).

6/ For example, the "Law of International Water Resources", FAO Legislation Branch, Paper No. 1 (Rome, 1970) and reports of the International Law Commission on the work of its twenty-sixth and twenty-eighth sessions dealing with the law of the non-navigational uses of international water courses (A/9610, vol. II, and A/CN.4/L.249, chap. V, respectively).

7/ The Executive Director of UNEP has prepared for the Governing Council an informative document on the subject entitled "Draft principles of conduct for the guidance of States in the conservation and harmonious exploitation of natural resources shared by two or more States" (UNEP/IG.2/2).

Provision of technical assistance, financing and training

65. The United Nations Development Programme has financed and assisted in various ways other United Nations agencies and the Secretariat, as well as regional organizations, in executing development projects (a total of 30 up to January 1975) on a large number of international river basins. 8/ The executing organizations, such as the Centre for Natural Resources, Energy and Transport of the Department of Economic and Social Affairs of the United Nations Secretariat, FAO, United Nations Educational, Scientific and Cultural Organization, World Health Organization, World Meteorological Organization, the World Bank and regional organizations such as the Organization of American States and the Inter-American Development Bank, provide the technical support directly or supervise the work done either by individual experts or consultant firms. In addition, UNDP assists in the provision of fellowships abroad and training of local personnel during the execution of projects and arranges the delivery of all the equipment needed for project implementation. In several international rivers projects, UNDP, as the executing agency itself, provided the technical supervision services.

66. The World Bank already has a long experience in financing and assisting international rivers development projects. Over the 30 years of its life, the Bank has been involved in 29 projects dealing directly with the development of international rivers and river basins. In addition to providing capital funds and technical assistance, the World Bank has on several occasions, more conspicuously in the case of the Indus Basin, provided its good offices to assist in resolving disputes.

67. In general, therefore, these global and regional organizations have provided much needed technical and financial assistance in specific international river basins, which have not only aided the co-operating States in developing the information required to plan and assess potential development schemes but it has also helped to strengthen the technical capabilities of national organizations, particularly through training of national personnel to carry out these works by themselves, which is the ultimate goal of any aid programme.

IV. CONCLUDING OBSERVATIONS

68. Several important conclusions emerge from the analysis of these experiences with international river basin co-operation. First, as has been previously emphasized, there is no substitute for the will to co-operate on the part of the co-riparian nations in each situation where a water resources system is shared by two or more nations. Without the will to co-operate little can be done to arrive at efficient and equitable management and use programmes.

8/ For a complete list of technical assistance projects carried out by the United Nations system and several other global and regional organizations, see the document mentioned in foot-note 2.

69. Secondly, where the will to co-operate exists, it is of critical importance that each riparian nation understand fully what potential management and use schemes exist and what physical, economic and social consequences and uncertainties are associated with each scheme. For a State to acquire the information on which to base such understandings with full confidence that the information is reliable, it should have its own strong national water organizations on which to rely.

70. Thirdly, river basin organizations and procedures for exchanging data and resolving technical differences can be invaluable in building a foundation of mutual trust and confidence among the riparian States. Such a foundation provides a solid basis for the political negotiations that every agreement requires.

71. Fourthly, since in many cases an economic incentive does not exist to negotiate an efficient and equitable agreement regarding the management and use of international water resources, it is important to build a consensus on legal principles which should govern the development and use of such resources. Some general principles of global applicability could be developed based upon the experience accumulated in reaching bilateral, multilateral and regional agreements on management of shared water resources. In addition, in particular regions a set of regional principles is needed, such as those the Council of Europe is devising, to govern the control of pollution on international rivers in that region.

72. The foregoing points provide some guidelines on how the international community can be of greatest assistance in promoting agreements on the management and use of international water resources. In some situations, the possibility of creating regional training and information centres should be explored. In this way, the needs of groups of countries in specific technical fields, which they otherwise could not independently afford to create would be satisfied. It might also be useful to consider promoting an exchange of personnel engaged in international water resources management, both as a device to train management staff and as a means of sharing and disseminating experience in applying criteria and methods for the collection, storage, retrieval and standardization of basic basin data.

73. International organizations and individual nations could continue to publish technical information and provide technical assistance in investigating and planning specific programmes. This review suggests that the primary thrust of efforts of the international community could be towards the following:

(a) Providing technical and educational assistance to strengthen national water agencies so that each riparian nation engaged in an effort to achieve agreement on an international water resource will have a capable professional staff of adequate size on which to rely for technical investigations and analysis;

(b) Providing capital funds where such funds are urgently needed to implement an agreed-upon scheme of development and management for a specific international water resource system;

(c) Global organizations should seek to devise and foster consensus on principles of general applicability which should govern the management of international water resources, while each regional organization should try to promote consensus on principles that are particularly applicable within its region.

74. It is believed that vigorous pursuit of these activities will be of invaluable assistance to the riparian States involved in each situation which, in the final analysis, have the responsibility for negotiating and implementing the programmes to be undertaken.

Annex

SELECTED EXPERIENCES IN INTERNATIONAL INLAND WATER RESOURCES DEVELOPMENT AND MANAGEMENT

D. A. Caponera (Food and Agricultural Organization), "The Senegal basin"

N. Cordeiro (Organization of American States), "The Pilcomayo River basin"

G. Epler (Council of Europe), "Common water quality standards for international watercourses: an example of long-term regional co-operation"

A. B. Futa (Volta River Authority, Ghana), "The development of the Volta River: co-operation between co-basin countries"

F. L. Hotes (World Bank) and K. Guiness (Consultant to the World Bank), "Special considerations for World Bank projects on international waters"

A. C. Kiss (Centre national de la recherche scientifique, France), "Gestion et mise en valeur des eaux intérieures internationales: le Rhin

D. G. LeMarquand (Westwater Research Centre, Canada), "International development of the Columbia River"

C. Sepulveda (International lawyer, Mexico), "Una experiencia en la administración de aguas fluviales internacionales: El Rio Colorado como cuenca internacional"

P. Shallow (United Nations Development Programme), "Case study of the integrated development of the Vardar-Axios River basin"

T. U. Torti (Ministry of Finance and Development, Nigeria), "Key factors responsible for the planning, development, and management of the Niger international river basin in West Africa"